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Research Document 2006/077 | **Document de recherche 2006/077**

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A review of quillback rockfish *Sebastes maliger* along the Pacific coast of Canada: biology, distribution and abundance trends

Examen du sébaste à dos épineux *(Sebastes maliger)* dans les eaux baignant la côte canadienne du Pacifique : biologie, répartition et tendances en matière d'abondance

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ISSN 1499-3848 (Printed / Imprimé)
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Abstract

This paper compiles information on the distribution, biology, abundance and abundance trends of quillback rockfish *Sebastes maliger*, in Canada, for use in a Committee on Endangered Wildlife in Canada (COSEWIC) status report. Quillback rockfish are found in the northeast Pacific from southern California to the Gulf of Alaska. In British Columbia (BC), there is presently no genetic evidence of multiple populations of quillback rockfish in BC. This species is observed from submersibles between 16 and 182 metres in depth over substrates that are hard, complex and vertically steep. Fisheries catch quillback rockfish over an estimated 27,370 square kilometres in BC. Quillback rockfish are aged to 95 years in BC and 50% of individuals 11 years of age are sexual maturity. Generation time is defined as the mean age of reproductive females and is estimated at 22.8 years. Females tend to be larger and older than males and reach a maximum size of 50 cm in BC. Total mortality rate ranges from 0.05 to 0.12 depending on the model used and natural mortality is estimated at 0.02 using catch curve analysis. Abundance is estimated at 2.23 million quillback rockfish in the 527 square kilometre survey area in the Strait of Georgia and 2.08 million over the 218 square kilometre study area in Juan Perez Sound. Fishery dependant catch per unit of effort (CPUE) is heavily influenced by management actions applied to the fishery and can not be used to interpret population trends. Abundance trends may be determined from research surveys which show either no-trend or a declining trend in abundance. The greatest decline has been 75% over 18 years between 1986 and 2004 within a study area located in the northern inside waters.

Résumé

Ce document rassemble des données sur la répartition, la biologie et les tendances en matière d'abondance du sébaste à dos épineux, *Sebastes maliger*, au Canada. Cette information sera utilisée dans un rapport de situation du Comité sur la situation des espèces en péril au Canada (COSEPAC). On trouve le sébaste à dos épineux dans le nord-est du Pacifique, du sud de la Californie jusqu'au golfe de l'Alaska. En Colombie-Britannique (C.-B.), il n'existe présentement aucune preuve génétique de populations multiples de sébaste à dos épineux. Cette espèce est observée, au cours de plongées sous-marines, entre 16 et 182 mètres de profondeur sur des substrats durs, complexes et abrupts. Les pêcheurs capturent le sébaste à dos épineux sur une étendue approximative de 27 370 km^2 en C.-B. Le sébaste à dos épineux peut atteindre 95 ans en C.-B. et 50 % des poisons ont atteint la maturité à 11 ans. La durée de génération se définit comme l'âge moyen des reproductrices et est estimé à 22,8 ans. Les femelles sont généralement plus grosses et plus âgées que les males, atteignant une taille maximale de 50 cm en C.-B. Le taux de mortalité totale varie entre 0,05 et 0,12, selon le modèle utilisé et le taux de mortalité naturelle est évalué à 0,02 à l'aide de l'analyse de la courbe de captures. On estime l'abondance à 2,23 millions de sébastes à dos épineux dans la zone de relevé de 527 km^2 dans le détroit de Georgia et à 2,08 millions dans les 218 km^2 de la zone d'étude de la baie Juan Perez. Les prises par unité d'effort basées sur la pêche sont fortement influencées par les mesures de gestion appliquées à la pêche et ne peuvent être utilisées pour interpréter les tendances de la population. Les tendances de l'abondance peuvent être déterminées à partir des relevés scientifiques à long terme qui révèlent soit une tendance à la baisse, soit aucune tendance particulière. La baisse la plus forte a été de 75 % au cours de la période de 18 ans, entre 1986 et 2004, dans une zone d'étude située dans les eaux internes du nord.

SPECIES INFORMATION

Name and classification

The quillback rockfish (*Sebastes maliger*) is one of 102 species of rockfish belonging to the genus Sebastes of which 96 are found in the North Pacific. The scientific names are from the Greek *sebastos* (magnificent) and the Latin *malus* and *gero* meaning "mast" and "to bear" (Hart 1973), translating into "I bear a mast" referring to the high dorsal fin (Love et al. 2002) In Canada's Pacific waters 36 species of rockfish have been found (Peden and Gillespie unpublished data). At present time there are no identified subspecies of quillback rockfish. Quillback rockfish have been referred to by other names including speckled rockfish, orange-spotted rockfish, and yellow backed rockfish (Lamb and Edgell 1986). From a Canadian management perspective, quillback rockfish are classified as "inshore" rockfish and are managed alongside yelloweye rockfish (*S. ruberrimus*), copper rockfish (*S. caurinus*), China rockfish (*S. nebulosus*), black rockfish (*S. melanops*) and tiger rockfish (*S. nigrocinctus*).

Morphological description

Quillback rockfish are most readily distinguished from other similarly looking rockfish by their high, deeply incised dorsal fin (Hart 1973; Love et al. 2002) (Figure 1). Adults are primarily brown with yellow to orange anterior blotches and with light coloured dorsal saddle patches that extend into the dorsal fin (Love et al. 2002). Their heads may be speckled with orange and brown dots which extend ventrally to just past the pectoral fins. Quillbacks found in Puget Sound do not have the speckled pigmentation (Love et al. 2002). All fins are dark in colour with the exception of the dorsal fin which has a lightly coloured band extending from the saddle patch.

Figure 1. Photograph of a quillback rockfish taken in the Strait of Georgia, BC. Photo credit: Lynne Yamanaka.

Genetic Description

Geographic variation accounted for less than 1% of the observed genetic variation in a microsatellite survey of over 1,500 quillback rockfish captured in coastal waters of British Columbia (BC) and in Puget Sound in Washington State. The genetic data did not refute the null hypothesis that all samples were drawn from a single population.

Samples obtained between 1997 and 2001 have been analyzed at 17 loci (Table 1). Sample sites included in the study ranged from Puget Sound to the Queen Charlotte Islands, with samples both on the west and east coasts of Queen Charlotte Islands and Vancouver Island. Analysis of variation at the 17 loci over the entire data set was carried out using GDA (Lewis and Zaykin 2001), FSTAT (Goudet 2001) and Bottleneck (Cornuet and Luikart 1996).

All 17 microsatellite loci examined were highly polymorphic in all 16 samples. The numbers of alleles observed at each locus and the observed and expected (under conditions of Hardy-Weinberg equilibrium) heterozygosities across all loci for each sample indicated a high level of intraspecific genetic variation (Table 2). The level of polymorphism was high, with an average of 21 alleles observed at the 17 microsatellite loci (Table 3). Moderate to high levels of expected heterozygosity at all loci (mean of 72%, range 41% to 89%) also indicated that the effective population size for quillback in BC was large.

Table 1. Quillback rockfish samples collected between 1997 and 2001 and included in the analysis of variation at 17 microsatellite loci.

Sample Location	Region	Collection Date	Sample Size
Hecate Strait	QCI	May 2000	41
Stenhouse Reef	QCI	Feb Sep 2000	103
Tofino	WCVI	Feb 2001	87
Area12	ECVI	Mar Apr 2001	543
Georgia Strait	ECVI	Oct 1998	32
Cooper Reef	ECVI	Sep 2000	67
Pylades Channel	ECVI	Oct 2000 May 2001	128
Gordon Channel	ECVI	Oct 2000	92
Gulf1	ECVI	1997	126
Gulf2	ECVI	1997	63
Gabriola	ECVI	Sep 2000 May 2001	85
Race Rocks	ECVI	Sep 2000	55
Juan de Fuca	SCVI	1988	22
Elliot Bay	Puget Sound	1998	76
Port Gardner	Puget Sound	1998	12
Foulweather Bluff	Puget Sound	1997	24
Total			1556

Table 2. Levels of genetic variation at 17 microsatellite loci in quillback rockfish collected between 1997 and 2001. All samples were combined for sites sampled multiple times. The level of genetic diversity is the expected heterozygosity (He) expressed as a percentage. Fis is the inbreeding coefficient calculated from observed (Ho) and expected (He) heterozygosities. The asterisk (*) indicates a significant departure from Hardy Weinberg equilibrium in sth56, and this locus was dropped from further analysis.

Locus	N	A	He	Ho	Fis
sal1	1230	12	0.791	0.80[illegible]	-0.014
sal2	1465	16	0.697	0.696	0.002
sal3	1503	15	0.602	0.611	-0.014
sal4	1333	8	0.689	0.666	0.034
seb9	1464	13	0.652	0.659	-0.011
seb33	1509	20	0.749	0.746	0.004
sme2	1441	27	0.892	0.879	0.014
sme3	1442	32	0.892	0.889	0.003
sme7	1529	21	0.774	0.773	0.001
sme8	1443	14	0.648	0.669	-0.032
sra5	1454	8	0.660	0.653	0.011
sra15	1352	16	0.793	0.803	-0.012
sra16	1499	31	0.832	0.839	-0.008
sru9	1408	33	0.794	0.799	-0.006
sth3b	1461	22	0.544	0.556	-0.023
sth37	1436	4	0.412	0.426	-0.035
sth56	1265	60	0.790	0.571	0.278*
Mean	1426	20.71	0.718	0.708	0.011

Levels of genetic diversity (He) did not vary significantly among sites, with a range within sites of 67.3% to 73.2% (Table 3). Numbers of alleles per site ranged from 7 to 15 but closely reflected the number of samples per site.

Allele frequency distributions showed that there was little differentiation of coastal quillback rockfish along the coast of BC, and that the most distinctive sites were found within Puget Sound (Tables 4). Analysis of gene diversity among the 16 quillback samples indicated that over 99.5% of the observed genetic variation occurred within samples and less than 0.5% was attributable to differentiation among samples. Although no significant affect of region was apparent from the AMOVA, a neighbor-joining dendrogram clustered sites into three regions: QCI/NCVI, WCVI, and Puget Sound (Figure 2). Estimates of pairwise F_{ST} values among sample sites ranged from less than zero to 0.013 and averaged 0.0032 (Table 4). Note that the highest F_{ST} values were observed between Port Gardner and other sites, but given the small sample size in Port Gardner (only 12 fish), most were not significant. Pairwise values within the three regions depicted in the dendrogram ranged from less than zero (QCI) to 0.0027 (Puget Sound). The most distinctive region along the coast was Puget Sound, with pairwise F_{ST} values between sites in Puget Sound and QCI averaging 0.0067 and WCVI averaging 0.0053, over two times the levels of differentiation observed within Puget Sound. However, only a small percentage of the individual comparisons were statistically significant.

Table 3. Levels of genetic variation at 17 microsatellite loci in quillback rockfish collected between 1997 and 2001. All samples were combined for sites sampled multiple times. The level of genetic diversity is the expected heterozygosity (HE) expressed as a percentage.

Population	Sample Size	Alleles	Genetic diversity
Hecate Strait	41	8.33	0.680
Stenhouse Reef	103	11.39	0.711
Tofino	87	9.78	0.709
Area12	543	15.94	0.718
Georgia Strait	32	7.78	0.715
Cooper Reef	67	9.89	0.689
Pylades Channel	128	11.89	0.673
Gordon Channel	92	10.00	0.716
Gulf1	126	11.50	0.726
Gulf2	63	10.33	0.732
Gabriola	85	11.22	0.719
Race Rocks	55	10.06	0.713
Juan de Fuca	22	7.44	0.686
Elliot Bay	76	10.50	0.716
Foulweather Bluff	24	10.27	0.722

From the results of this analysis, we cannot reject the null hypothesis that only a single population of quillback rockfish exists within British Columbia. Although not entirely statistically supported, it was clear that the Puget Sound sites were the most distinctive sites analyzed, but this result should be followed up with greater sample sizes and multi-year sampling. Our data were consistent with the findings of the US review (Stout et al. 2001), which showed that the Puget Sound Basin Proper was distinctive from coastal Washington sites, but no significant differences were observed among coastal sites. Our Puget Sound samples were not in Puget Sound Basin proper, and hence were likely somewhat less distinctive than those of the previous study.

In Washington State, three distinct population segments (DPS) for quillback rockfish are recognized, based largely on biogeography, ecological and habitat factors and genetic population structure (Stout et al. 2001). These are defined as a Puget Sound proper DPS, a northern Puget Sound DPS and a coastal DPS but the boundaries are uncertain. Genetic evidence from allele and microsatellite analyses by Seeb (1998) and Wimberger et al. (in prep) were used to support the DPS scenario for quillback rockfish. Seeb (1998) found some evidence that quillback rockfish in Puget Sound may be genetically isolated from those along the Pacific Coast.

Table 4. Pairwise values of F_{ST} between quillback rockfish samples from sites between Queen Charlotte Islands and Puget Sound, Washington are shown below diagonal. The significance of pairwise tests of differentiation (of allele frequencies) between samples (with Bonferroni corrections for multiple tests) is shown above the diagonal. For these tests, Ns indicates that there were no differences in allelic frequencies between sites and an asterisk (*) indicates that the allele frequencies in the two samples differed (P<0.05).

	Georgia Str.	Race Rock	Cooper Reef	Pylades Channel	Gordon Channel	Gulf1	Gulf2	Elliot Bay	Port Gardner	Foulweather Bluff	Juan Fuca	Gabriola	Area12	Tofino	Hecate Strait	Stenhouse Reef
Georgia Strait	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Race Rocks	0.0010	Ns	Ns	Ns	Ns	*	*	*	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Cooper Reef	0.0025	0.0015	Ns	Ns	*	Ns	Ns	Ns	Ns	Ns	Ns	*	Ns	Ns	Ns	Ns
Pylades Channel	0.0023	0.0025	0.0010	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns	*	Ns	Ns	Ns	Ns
Gordon Channel	0.0011	0.0021	0.0042	0.0022	Ns	*	*	*	Ns	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Gulf1	0.0009	-0.0002	-0.0004	-0.0003	0.0023	Ns	Ns	*	Ns	Ns	Ns	*	Ns	Ns	Ns	*
Gulf2	0.0051	0.0062	0.0006	0.0047	0.0074	0.0010	Ns	Ns	Ns	Ns	Ns	*	Ns	Ns	Ns	*
Elliot Bay	0.0031	0.0034	0.0016	0.0026	0.0049	0.0017	0.0034	Ns	Ns	Ns	Ns	*	Ns	Ns	Ns	*
Port Gardner	0.0033	0.0110	0.0042	0.0099	0.0126	0.0083	0.0046	0.0028	Ns	Ns	Ns	*	Ns	Ns	Ns	Ns
Foulweather Bluff	0.0013	0.0042	0.0040	0.0033	0.0058	0.0019	0.0025	-0.0006	0.0003	Ns	Ns	Ns	Ns	Ns	Ns	Ns
Juan Fuca	0.0010	-0.0012	0.0024	0.0039	0.0046	0.0011	0.0060	0.0047	0.0056	0.0061	Ns	Ns	Ns	Ns	Ns	Ns
Gabriola	0.0030	-0.0020	0.0027	0.0003	0.0037	0.0009	0.0063	0.0049	0.0130	0.0043	-0.0009	Ns	Ns	Ns	Ns	Ns
Area12	0.0015	-0.0005	0.0024	0.0006	0.0026	0.0006	0.0073	0.0033	0.0136	0.0036	0.0030	0.0010	Ns	Ns	Ns	Ns
Tofino	0.0023	0.0006	0.0031	0.0017	0.0031	0.0014	0.0052	0.0041	0.0121	0.0054	0.0001	0.0012	0.0007	Ns	Ns	Ns
Hecate Strait	0.0017	-0.0021	-0.0011	0.0009	0.0010	0.0010	0.0048	0.0046	0.0117	0.0061	-0.0015	-0.0006	0.0001	-0.0010		
Stenhouse Reef	0.0036	0.0016	0.0027	0.0017	0.0041	0.0022	0.0071	0.0051	0.0127	0.0016	0.0036	0.0018	0.0008	0.0005	0.0005	

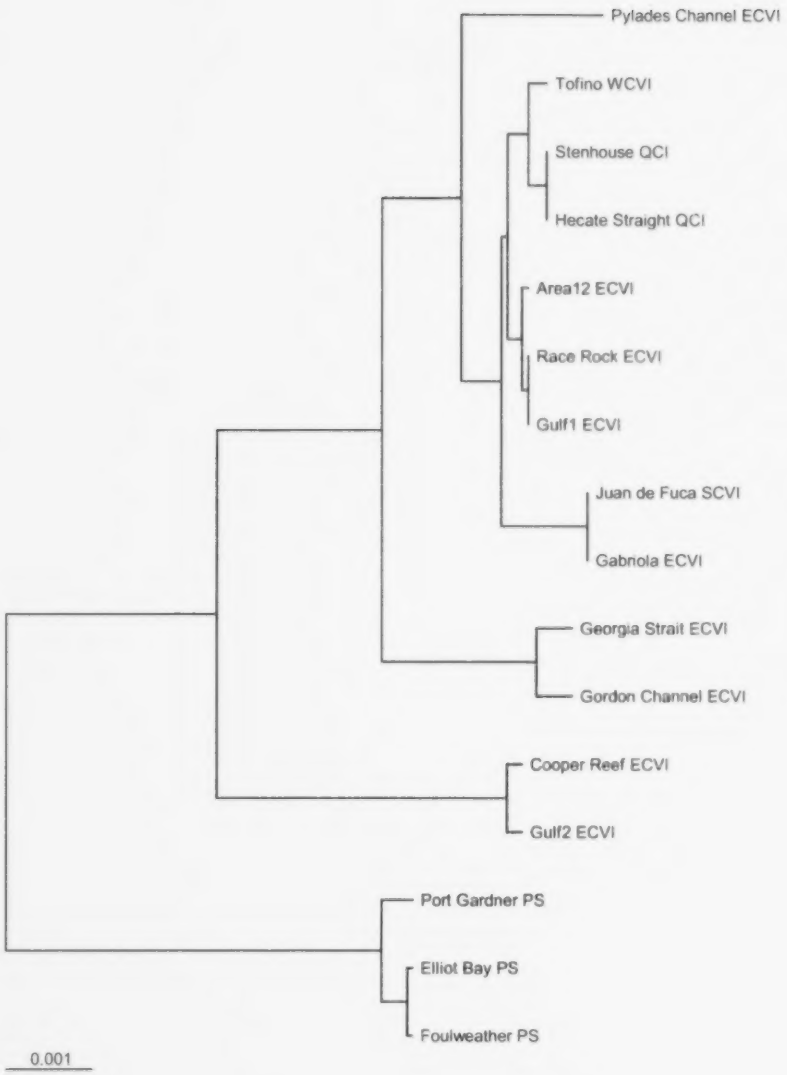

Figure 2. UPGMA tree of Quillback rockfish samples collected between 1997 and 2001 between Queen Charlotte Islands to Puget Sound. The dendrogram was constructed based on Nei's (1978) standardized genetic distance (DS) values.

Designatable Units

There is presently no genetic basis to assign multiple designatable units for quillback rockfish within BC. The fishery for inshore rockfish has traditionally been managed separately for the inside (water between the East side of Vancouver Island and the mainland) and the remainder of the coast outside of the Strait of Georgia.

DISTRIBUTION

Global Distribution

Quillback rockfish have been reported from Kodiak Island, Gulf of Alaska (Mecklenberg et al. 2002) to Anacapa Passage (Love and Lea 1997), southern California (Figure 3; Love et al. 2002).

Figure 3. Global distribution of quillback rockfish reprinted with permission from Love et al. (2002).

Canadian range

Quillback rockfish range throughout the marine waters of BC on Canada's Pacific Coast. Commercial hook and line and trawl fisheries operating in BC report catches by species and location to Fisheries and Oceans Canada (DFO). These data are archived in the DFO databases PacHarvHL and PacHarvTrawl. The distribution of commercial catch records for quillback rockfish, for the years 1996 to 2004, is shown in Figure 4.

This distribution of quillback rockfish in the commercial fishery depicts the Canadian range of the species.

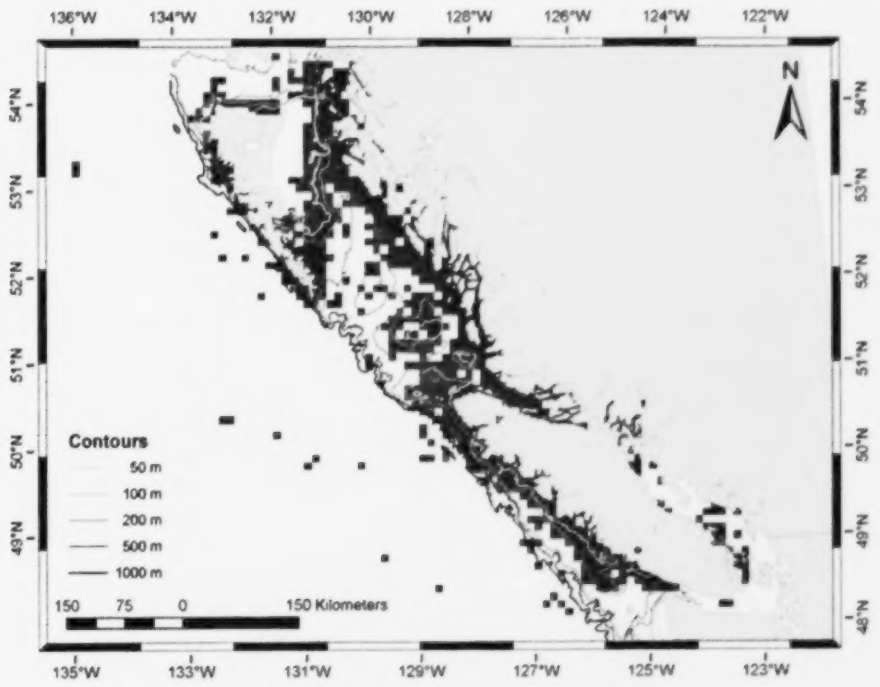

Figure 4. Distribution of quillback rockfish in BC from commercial hook & line and trawl catch records (1996 - 2004) summarized on a 10 by 10 km coastwide grid.

A generalized distribution of commercial catch (hook & line and trawl) by depth interval is derived by overlaying a bathymetric grid on the catch records and summarizing data over a 10 X 10 km grid. Area occupied by quillback rockfish is shown in Table 5. Quillback rockfish are most widely caught in the 51-100 m depth range where catches are recorded in 84.5% of the area. This species is not endemic to Canada and its Canadian distribution is approximately 25% of their global range (Love et al. 2002).

Table 5. The total surface area (km^2) of marine water in BC by depth interval (m) from 1 to 2000 m (based on map bathymetry), area with quillback rockfish commercial catch recorded and the percentage of the total surface area with quillback rockfish catch recorded for the years 1996 – 2004 combined.

Depth Interval (m)	Total Area (km^2)	Occupied Area (km^2)	Percent Occupied
1-50	23,254	13,540	58.2
51-100	20,311	17,170	84.5
101-200	36,432	21,182	58.1
201-500	26,510	7,775	29.3
501-1000	7,473	1,492	20.0
1001-1500	8,480	1,207	14.2
1501-2000	10,679	780	7.3
Total:	133,139	63,146	47.4

The distribution of quillback rockfish was examined, for all depths combined, by year to determine temporal changes. The percent of total area with quillback rockfish commercial catch is determined annually from 1996 to 2004 (Table 6). The commercial hook & line and trawl fisheries have been established for many years prior to 1996 and logbook records have been routinely compiled for the ZN (rockfish by hook & line) and trawl fisheries (Yamanaka and Lacko 2001).

Table 6. The total number of blocks (10 x 10 km grid) fished the total number of blocks with a recorded quillback rockfish catch (commercial hook and line and trawl) and the percent of blocks with quillback rockfish catch by year (1996-2004).

Year	Blocks Fiished	Blocks Occupied	Percent
1996	1307	583	44.6
1997	1120	521	46.5
1998	1133	517	45.6
1999	1128	493	43.7
2000	1173	484	41.3
2001	1621	583	36.0
2002	1405	420	29.9
2003	1324	422	31.9
2004	1227	386	31.5

In 2001, new logbooks for the Schedule II fisheries (directed lingcod and dogfish by hook & line gear) were implemented and compiled in PacHarvHL for the first time. This effectively increased the number of blocks fished by the commercial fisheries but quillback rockfish were likely under reported in the new Schedule II logbook records due to the mandatory non-retention of rockfish in this fishery. Incidental rockfish catches were likely discarded at-sea and not reported on logbooks. As a result, the percent of occupied blocks in 2001 to 2004 appears to be lower than in years prior to 2001 but may not indicate a contraction of area occupied by quillback rockfish.

Catch quotas for quillback rockfish were lowered dramatically, by 50% in outside areas and 75 % within inside waters, between 2001 and 2002. In general, the lowering

of catch quotas would have the effect of lowering fishing activity (blocks fished as well as blocks occupied) but may also increase the non-reporting of quillback catch in logbooks. It is uncertain whether the declines in the percent distribution of quillback rockfish are real or a result of significant management actions applied to the commercial fisheries.

Examining the depth of capture for quillback rockfish recorded from commercial hook and line and trawl fishery logbooks, 95% of all observations lie between 14 and 143 meters in depth (Figure 5). An estimate of the maximum potential habitat area for quillback rockfish was derived by applying this depth range (surrogate for habitat), to bathymetry coastwide. Summarizing over a 5 x 5 km grid, an estimate of maximum potential habitat is 56,278 km^2 coastwide in BC (Figure 6). This is likely an overestimate of the true habitat area as quillback rockfish associate only with hard bottom substrates within their depth range. The habitat area with quillback rockfish catch, or occupied habitat area, is estimated at 27,370 km^2 or 48.6 percent of the maximum potential habitat area.

This estimate of maximum potential habitat does not differentiate between bottom types (it includes them all) and is likely an overestimate of the true habitat area as quillback rockfish associate only with hard bottom substrates within their depth range. The occupied habitat area is likely underestimated with this analysis because not all potential habitat areas of the coast have been fished.

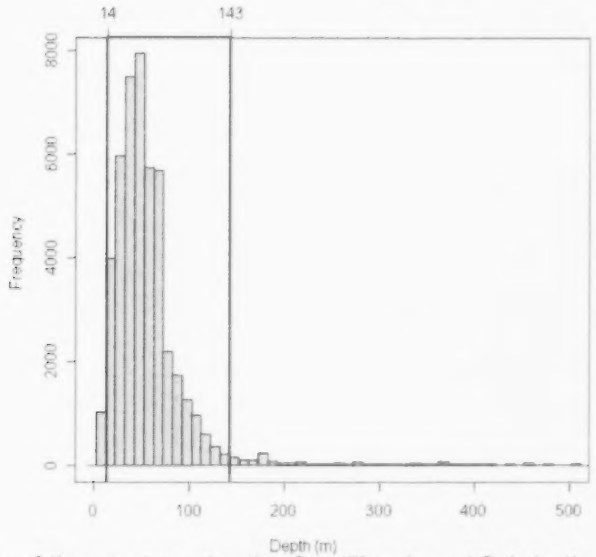

Figure 5. Histogram of the capture depth of quillback rockfish in the commercial hook & line and trawl fisheries in BC between 1996 and 2004. Vertical lines denote the 2.5% and 97.5% quartiles of the data.

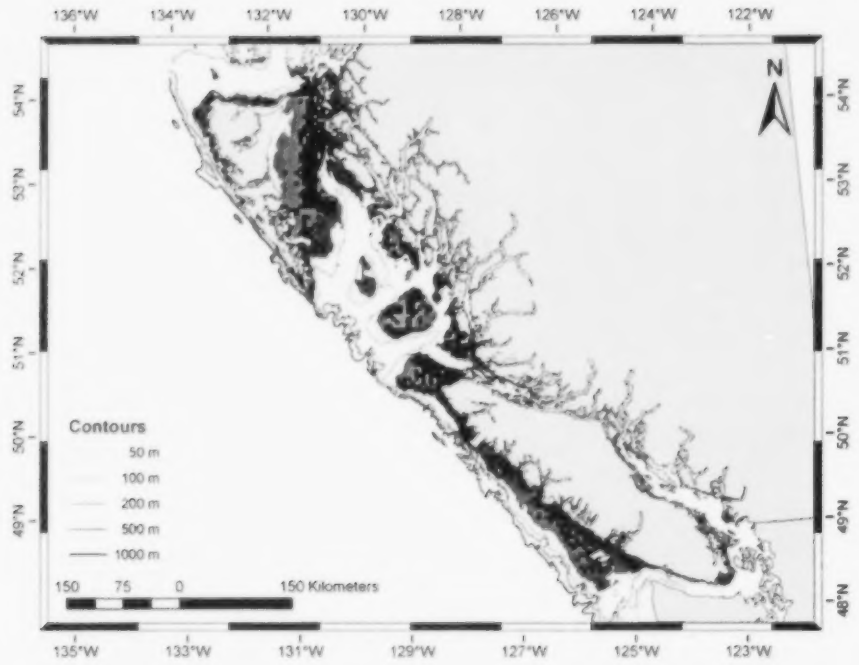

Figure 6. Maximum potential habitat of quillback rockfish in Canadian waters, based on the depth of capture range of 14 to 143 m, over a 5 x 5 km grid, is 56,278 square kilometers. The occupied habitat based on commercial fishing records is 27,370 square kilometers, or 48.6% of the potential habitat.

HABITAT

Habitat requirements

Quillback rockfish are habitat specialists, aggregating over substrates that are hard, complex and have some vertical relief, such as broken rock, rock reefs, ridges, crevices (Richards 1986, Matthews 1990, Murie et al. 1994). Information on the habitat of quillback rockfish from California through BC and in Alaska has come from direct *in situ* observations from submersibles, underwater towed cameras and divers using self contained underwater breathing apparatus (SCUBA).

Habitat trends

There are no data to substantiate habitat trends for quillback rockfish. It is assumed that there have been no net changes to the habitat (14-143 m depth range coastwide) since the last glaciation.

Habitat protection/ownership

Rockfish Conservation Areas (RCAs) are spatially defined areas where fishing is prohibited year round by both commercial and recreational sectors (http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/fisheriesmgmt/rockfish/default_e.htm). RCAs were developed in consultation with stakeholders and are used as a spatial management tool to protect a portion of the rockfish population from harvest. These RCAs are aimed at protecting rockfish by identifying rockfish habitat and closing a portion of these habitats to all harvesting activities. RCAs will remain closed into the future to support the rebuilding of inshore rockfish stocks. DFO has closed 20% of rockfish "habitat" within RCAs for the outside area in 2005 and has targeted 30% of rockfish "habitat" closed for the inside area in 2006.

BIOLOGY

Quillback rockfish have been sampled for biological data (length, weight, sex, maturity, age and DNA) by the Department of Fisheries and Oceans (DFO) since 1980. These data are archived in the DFO database GFBio. Samples are collected from commercial fishing vessels but fishery independent research surveys have also been conducted. Jig fishing surveys were conducted in 1986-88 and again in 1992 and 2004 at study sites in Johnstone Strait. Submersible surveys targeting inshore rockfishes were conducted in the Strait of Georgia in 1984 (Richards and Cass 1985), in the Gulf Islands and Desolations Sound in 2003 (Yamanaka et al, 2004) and Juan Perez Sound, Desolation Sound and Jervis Inlet in 2005 (Yamanaka in prep). A towed camera survey was conducted within the Strait of Georgia in 2003 (Martin and Yamanaka 2004). Fishing research surveys have provided the most samples used here to characterize populations and the submersible surveys have provided information on depth ranges for adult and juvenile fish. For other information in this section, research largely from the U.S. has been used to characterize aspects of quillback rockfish biology that have not been directly studied in BC.

Life cycle and reproduction

In BC the mating season for quillback rockfish is most likely in December when males gonads are known to be in "running ripe" condition and may extend from November to February (Yamanaka unpublished data). Females can mate with several males and store sperm for several weeks prior to fertilizing the eggs (Wyllie Echeverria 1987). Rockfishes are matrotrophically viviparous, supplying nutrients to the developing embryos late in their development (Boehlert and Yoklavich 1984, Yoklavich and Boehlert 1991). The gestation period is generally between one to two months for rockfishes (Love et al. 2002). Parturition for quillback rockfish in BC occurs between March and July with a peak in April and May (Yamanaka unpublished data).

The duration of the pelagic larval phase of quillback rockfish is unknown but *Sebastes*, in general, have a prolonged pelagic larval period lasting for one to two

months. Larvae and juveniles occur in the upper mixed layer (<300 m) and are dispersed by physical transport processes (Loeb et al. 1995, Kokita and Omori 1999). In the pelagic environment the small (3-7 mm) larvae develop into pelagic juveniles (20 to 70 mm) prior to settling in benthic habitats (Bjorkstedt et al. 2002). Sebastes larvae are opportunistic feeders known to feed initially on copepod nauplii and invertebrate eggs, moving onto larger prey such as copepodites, adult copepods, and euphausiids as they grow (Moser and Boehlert 1991). Settlement occurs when the pelagic juveniles reach 3 - 9 cm and 6 - 9 months of age (Love et al. 2002). Benthic juveniles continue to feed on crustaceans but shift to larger prey from planktonic to benthic species then onto fish (Love et al. 1991). The recruitment of rockfish is influenced to a large extent by their success during these pelagic larval-juvenile and benthic settlement phases.

Typically, rockfish juveniles settle to near shore hard bottom habitats at shallower depths than their conspecific adults. This appears to hold true for quillback rockfish observed from submersibles at all coastal BC locations surveyed (Table 7). Rockfish move bathymetrically with age, hence the older (larger) rockfish tend to occupy the deeper depths within their specific depth range (Love et al. 1991). Quillback rockfish are known to have limited home ranges (30 m^2) and have the ability to return to their home reef after displacements of 500 M (Matthews 1989).

Submersible surveys conducted in B.C. have observed quillback rockfish at various locations coastwide in 1984, 2000, 2003 and 2005 (Richards 1986, Murie et al. 1994, Yamanaka unpublished data). Sub-adult and adult quillback rockfish (>20 cm forklength) have been observed from submersibles in BC hovering near or settled upon rock ridges and occupying crevices in rock substrates from 22 to 182 m in depth with a median of all observations of 60 m (Table 3.).

Table 7. Minimum, 25th percentile, median, 75th percentile, maximum depth and number (n) of sub-adult and adult quillback rockfish greater than 20 cm in forklength observed during submersible surveys coastwide and by site.

Quillback Rockfish >20cm	Year	min.	25%	median	75%	max	n
coastwide	all	22	45	60	88	182	568
Juan Perez Sound	2005	31	51	64	95	178	347
Desolation Sound	2003/05	22	31	40	60	178	121
Jervis Inlet	2005	24	46	62	88	178	85
Gulf Islands	2003	67	75	87	109	182	15

Juvenile quillback rockfish (<20 cm in forklength) have also been observed from submersibles in a shallower depth range than the adults, 16 to 159 m but with a similar median of all observations of 48 m (Table 8). Juveniles occupy similar rock habitats to the adults but are seen in areas with smaller crevice space available for refuge, including cloud sponge formations, crinoid aggregations on top of rocky ridges and over cobble substrates. Young of the year quillback rockfish have been observed by SCUBA divers in shallow water (< 60 ft) eel grass and kelp beds in the Strait of Georgia, BC

during the late summer and early fall (Richards 1987).

Table 8. Minimum, 25th percentile, median, 75th percentile, maximum depth and number (n) of juvenile quillback rockfish less than or equal to 20 cm in forklength observed during submersible surveys coastwide and by site.

Quillback Rockfish Juveniles (<=20cm)	Year	min.	25%	median	75%	max	n
coastwide	All	16	36	48	60	159	420
Juan Perez Sound	2005	30	43	49	52	121	82
Desolation Sound	2003/05	16	31	42	57	159	194
Jervis Inlet	2005	21	36	52	74	102	137
Gulf Islands	2003	41	48	58	76	120	7

Age and Growth

Quillback rockfish have been aged to 95 years in BC (Yamanaka and Lacko 2001). Size and age at 50% maturity is 29.3 cm (95% CI 28.9 – 29.7 cm) and 11 years (95% CI 10-12 yr) (Yamanaka and Richards 1993). The average age of mature females, assessed through historical biological samples from April to July is 22.8 (std dev = 12.36, n = 1,776) (Yamanaka unpublished data). This is an estimate of generation time for quillback rockfish as all mature individuals contribute to annual cohorts from the year they first produce larvae, until their death.

In the quillback rockfish population, there are equal numbers of males and females, the average age of both sexes is about 21 and the maximum age of females is older than that for males at 95 and 80 years, respectively (Table 9). Both the average and maximum forklength of females is slightly longer than that for males (Table 5 and Figures 7 and 8). Sexual dimorphism is common among rockfishes with females most commonly larger in size than the males (Wyllie Echeverria 1986). Forklength – weight relationship is shown in Figure 7 and forklength at age data fit to a von Bertalanffy growth function (von Bertalanffy 1938) is shown in Figure 8.

Table 9. Summary of biological sample data for quillback rockfish, including descriptive statistics on sex, age and forklength (source: DFO GFBio database 23/09/2005).

Quillback Rockfish	Males	Females
Number sexed	19677	19940
mean age	20.6	20.7
std dev of age	12.27	12.60
Number aged	6425	6683
Maximum age	80	95
mean forklength	308	313
std dev of forklength	98.9	95.3
Number of lengths	11746	11991
Maximum forklength	502	503

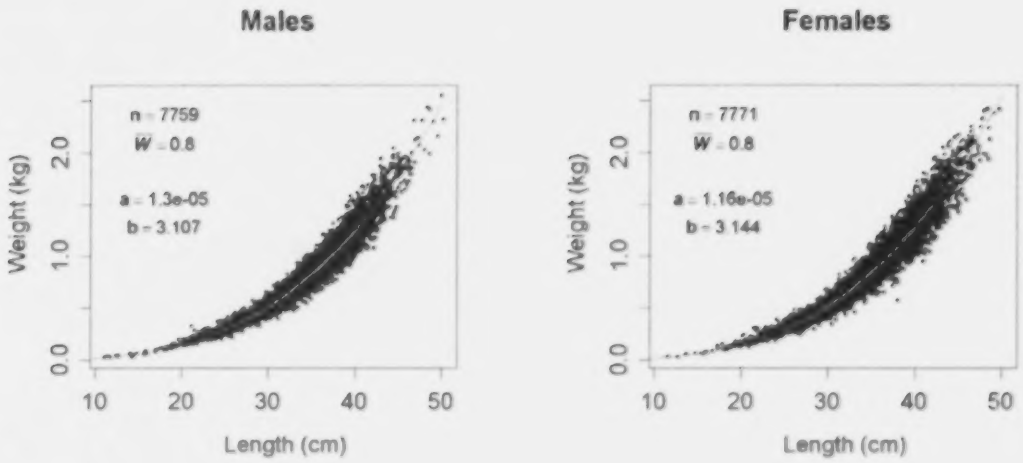

Figure 7. Quillback rockfish forklength (L in cm) vs weight (W in kg) by sex, $W = aL^b$.

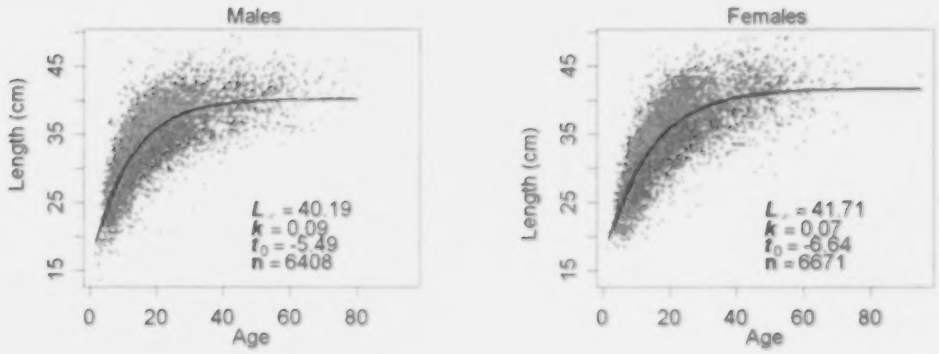

Figure 8. Quillback rockfish forklength (cm) at age (yrs) fit to the von Bertalanffy growth function by sex.

Mortality Rates

Simple catch curves were used in 2001 (Yamanaka and Lacko) to estimate total mortality (Z) for quillback rockfish from jig survey age data collected from 1986 to 2001. Using data from additional research surveys, simple catch curves were used to estimate Zs shown in Table 10. (Appendix A).

Table 10. Total mortality estimates (Z) from simple catch curves (Appendix A) by area, year and survey and the r^2 statistic for the regression line.

			Total mortality estimate (Ricker 1975)	
Area	Year	Survey	Z	r^2
Inside	1986-88	DFO research jig fishing	0.063	0.759
Inside	1992	DFO research jig fishing	0.068	0.642
Inside	2001	DFO research jig fishing	0.093	0.662
Inside	2004	DFO research jig fishing	0.046	0.388
inside	2003/04	DFO research longline	0.078	0.872

Catch curve methods of Schnute and Haigh (2006), allow for recruitment variability in the estimation of total mortality. These methods are applied to the same age data sets used in the simple catch curve analyses in Table 10. Total mortality for quillback rockfish from the research jig fishing survey data are shown in Figure 9 and for the research longline fishing survey data in Figure 10. Table 11 shows the total mortality estimates from the various survey data estimated using methods of Schnute and Haigh (2006).

Table 11. Total mortality estimates (Z) from Schnute and Haigh (2006) by area, year and survey showing the mean, mode and 2.5 and 97.5 percentiles of the posterior Z distributions.

			Total mortality estimate (Schnute and Haigh 2006)			
Area	Year	Survey	2.5%	mean	mode	97.5%
Inside	1986-88	DFO research jig fishing	0.047	0.059	0.059	0.069
Inside	1992	DFO research jig fishing	0.051	0.071	0.073	0.092
Inside	2001	DFO research jig fishing	0.061	0.109	0.124	0.140
Inside	2004	DFO research jig fishing	0.061	0.106	0.135	0.150
inside	2003/4	DFO research longline	0.049	0.057	0.065	0.066

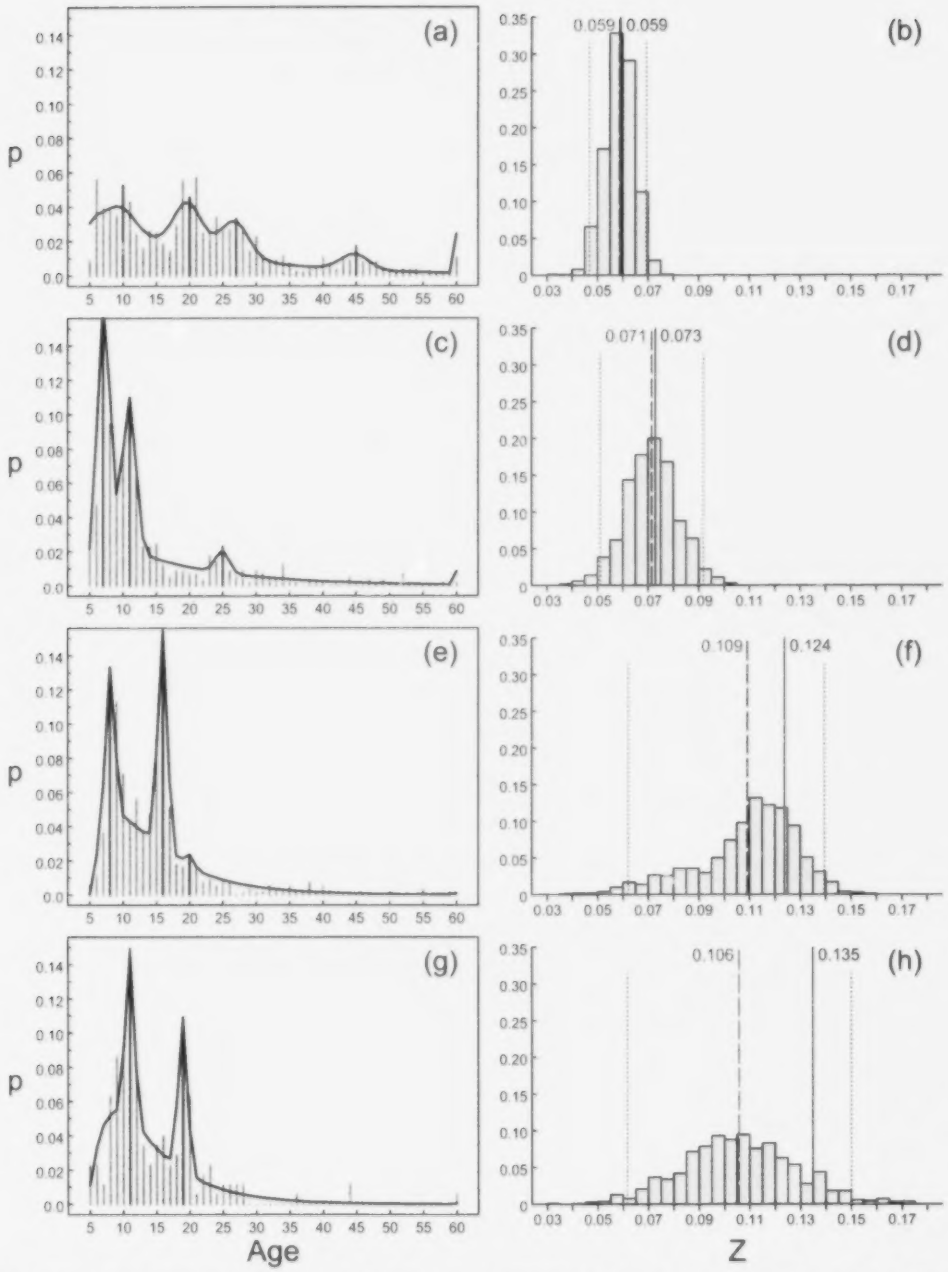

Figure 9. Catch-curve analysis for (a-b) combined 1986-88 survey data, (c-d) 1992 survey data, (e-f) 2001 experiment data, and (g-h) 2004 survey data. (a,c,e,g) Observed proportions-at age (vertical bars) and predicted (solid curves) using the catch-curve model in Schnute and Haigh (2006). The recruitment anomalies assumed are highlighted as dark vertical bars. (b,d,f,h) Posterior samples of Z as histograms. Solid vertical lines indicate the mode from the model fits. Dashed vertical lines indicate the mean Z-values, dotted vertical lines indicate the 2.5% and 97.5% quantiles.

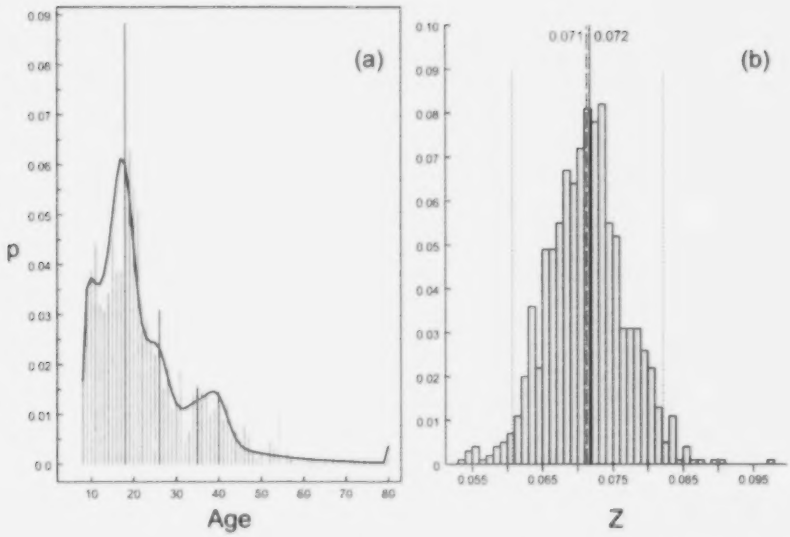

Figure 10. Catch-curve analysis for (a-b) combined 2003, 2004 longline survey data. (a) Observed proportions-at age (vertical bars) and predicted (solid curves) using the catch-curve model in Schnute and Haigh (2006). The recruitment anomalies assumed are highlighted as dark vertical bars. (b) Posterior samples of Z as histograms. Solid vertical lines indicate the mode from the model fits. Dashed vertical lines indicate the mean Z-values, dotted vertical lines indicate the 2.5% and 97.5% quantiles.

Diet

Most rockfishes are opportunistic feeders that take prey readily available to them and substituting prey items of the same general size and type (Rosenthal et al. 1988). As larvae and after settlement, quillback rockfish feed on planktonic animals and eggs. As adults they consume a variety of prey, fishes, benthic and pelagic invertebrates, especially shrimp (CDFG 2001).

Predation

Quillback rockfish larvae are preyed upon by jellyfish and arrow worms and the juveniles are preyed upon by fishes, marine birds, pinnipeds and the adults by larger fish, sea lions, seals and possibly river otters (CDFG 2001). In the Strait of Georgia, predation by harbour seals has been estimated at 112 t for all rockfish species in 1988 (Olesiuk et al. 1990). These rockfish were not identified to species but this marine mammal harvest may be significant compared to the all fishery harvest of 336 t in the Strait of Georgia in 1988.

Physiology

All rockfish have physoclistic swim bladders (lack a pneumatic duct) and must rely on a gas gland to fill the bladder. This gland is a highly vascularized and can push oxygen into the gland even against some very high pressures. To release gas from the swim bladder, the fish opens a set of constrictor muscles that allows the gas to escape the bladder and diffuse into the blood stream. Rockfish cannot rapidly accommodate changes in pressure and gas expansion in the swim bladder when brought to the surface from depth.

The mortality rate suffered by discarded rockfish is unknown. Based on shallow water fishing with handline gear and holding experiments, estimates of 30% mortality rate at 1-month post catch have been made for quillback rockfish (Berry 2001). Long-term mortality rates are likely higher for these fish as visible eye damage alone was noted for 55% of the catch. Rockfish discarded at-sea are considered part of the total catch.

Temperature and salinity were measured during submersible surveys conducted in 2003 and 2005 and are summarized for all observations of quillback rockfish in Table 12. The observed temperature ranges from 8.1 to 12.1°C and salinity ranges from 28.2 to 35 parts per thousand. The submersible surveys were conducted over a limited range of habitats in B.C. and likely represent a subset within the physiological tolerances of the species.

Table 12. Summary of temperature (°C) and salinity (parts per thousand) measured for all quillback rockfish observed during submersible dives in 2003 and 2005.

Quillback rockfish		
	Temperature	Salinity
Mean	9.13	32.83
Standard Error	0.0242	0.0708
Median	8.78	34.70
Minimum	7.96	28.19
Maximum	12.22	35.34
Count	1172	1172

Dispersal

Rockfish are known to passively disperse with ocean currents during their extended pelagic larval stage. *Sebastes* larvae were found to concentrate over the continental shelf and slope west of the Queen Charlotte Islands, up to 300 nmi from shore (LeBrasseur 1970). From the composition of otolith microstructure, there is evidence that dispersal may be less than 120 kms for black rockfish (*Sebastes melanops*) (Miller and Shanks 2004). Dispersal of larvae would immediately follow parturition which occurs from April to September for quillback rockfish. The actual dispersal distance for quillback rockfish is unknown.

Interspecific interactions

There are no known interspecific interactions that limit the survival of quillback rockfish in Canada.

Adaptability

Quillback rockfish have been captured from the wild and held in aquaria for display purposes but there are no known captive breeding programs or grow-out aquaculture operations for this species in Canada.

FISHERIES

Quillback rockfish are caught primarily by hook and line in Aboriginal, commercial and recreational fisheries coastwide (Yamanaka and Lacko 2001). Common gear types include rod and reel rigged with single or multiple hooks and operated manually by the fisher or longline systems with multiple hooks that are operated hydraulically. Rod and reel gear is jigged just off the bottom and longline gear is demersal. Quillback rockfish are also caught in trawl and trap fisheries coastwide. The largest landings of quillback rockfish are taken in the directed ZN rockfish fisheries and incidental catch is taken in all other commercial hook and line fisheries, such as those for halibut, dogfish, lingcod and salmon, as well as, groundfish and shrimp by trawl gear and prawn and sablefish by trap. Incidental catch is not known for fisheries where the landing of rockfish is either limited or prohibited by license conditions.

The fishery for quillback rockfish in the Strait of Georgia developed in the late 1970's in response to a growing demand for live fish in markets around Vancouver. Premium prices are paid for live rockfish, at least five times the price for fresh (dead) rockfish. The live market continues to thrive in the lower mainland. Fishery management for the Strait of Georgia management region (inside waters) is focused solely on a live rockfish fishery, in contrast to the outside area where there is more of a mix between live and fresh rockfish landed.

The directed commercial hook and line fishery for rockfish was licensed in 1986 (Yamanaka and Lacko 2001, Kronlund and Yamanaka 1997, Yamanaka and Kronlund 1997). Area licensing (inside or outside the Strait of Georgia Management Region) and catch quotas for each of five management regions were introduced in 1991. Limited entry licensing was implemented for the inside (Strait of Georgia) management region in 1992 and for the remainder of the coast (outside) in 1993. Limited entry licensing reduced the number of licences to 74 in the Strait of Georgia and to 183 licences outside from over 2400 licenses coastwide in 1986. The commercial fishery for quillback rockfish is managed by aggregate species TACs. Quillback rockfish are managed in and aggregate together with copper, china and tiger rockfishes.

Recreational harvests are managed by bag limits. In 1986 an eight rockfish daily

bag limit was implemented coastwide for the recreational fishery. In 1992 the daily bag limit for the Strait of Georgia recreational fishery was reduced from eight to five rockfish. Further reductions were implemented in 2002, from eight to five rockfish per day outside and from five to one rockfish per day inside.

In 1995, dockside monitoring of all commercial groundfish landings was initiated together with 100% at-sea observer monitoring for the commercial groundfish trawl fishery. Partial at-sea observer coverage for the commercial hook and line groundfish fleet was initiated in 1999. Incidental catch is not well known for unobserved commercial fisheries, especially where the landing of rockfish is either limited or prohibited by license conditions.

A rockfish conservation strategy (RCS) (http://www-comm.pac.dfo-mpo.gc.ca/pages/consultations/fisheriesmgmt/rockfish/default_e.htm) was announced by the Minister of Fisheries and Oceans in 2001 and focused on four principles:

1. account for all catch (landed and discarded)
2. reduce fishing mortality
3. areas closed to all fishing (Rockfish Conservation Areas (RCAs))
4. stock assessment

Strong management measures were implemented in 2002, including increased at-sea observer coverage on commercial hook and line fleets, commercial TAC and recreational daily bag limit reductions by 50% for areas outside and 75% for the outside, together with the implementation of 28 Rockfish Conservation Areas (RCAs) coastwide. Consultations in 2003/04 resulted in the closure of 20% of the "rockfish habitat" on the outside and a goal of 30% "rockfish habitat" closed is set for the inside with consultations completed in 2006. In 2002, overall TACs for the aggregate that includes quillback rockfish, were 148 t for the outside and 57 t inside.

In response to the Department's Rockfish Conservation Strategy, Pacific Fisheries Monitoring and Reporting Framework and Selective Fishing Policy as well as the Species at Risk Act, the commercial groundfish industry formed a committee, the Commercial Industry Caucus (CIC) to develop a pilot groundfish integration proposal that address these issues and others, to ensure a unified and sustainable groundfish fishery into the future (Diamond Management Consulting Inc. 2005). The CIC is committed to ecologically and economically sound practices and supports the general principles of the Oceans Act. The CIC has worked on this proposal since 2003 with implementation for the 2006 fishery.

The CIC is guided by the following five principals:

1. All rockfish catch must be accounted for,
2. Rockfish catches will be managed according to established rockfish management areas,
3. Fishermen will be individually accountable for their catch,

4. New monitoring standards will be established and implemented to meet the above 3 objectives, and,
5. Species of concern will be closely examined and actions such as reduction of total allowable catch (TAC's) and other catch limits will be considered and implemented to be consistent with the precautionary approach for management.

With integrated groundfish management, 100% at-sea monitoring standards will be in place for the entire groundfish fishery. This monitoring will eliminate unreported catch of rockfish throughout the commercial groundfish fishery and allow all rockfish to be accounted for within their TACs.

1. Commercial catch

Commercial hook & line landings and trawl catch (landings and discards) data are extracted from DFO sale slip records for "other rockfish" for the years 1951-1995 and from the integrated dockside monitoring and logbook DFO databases PacHarvTrawl and PacHarvHL for quillback rockfish for the years 1996-2004 (Figure 11 and Table 13). Species specific landed weights were verified by dockside monitoring programs implemented in 1995. Hook and line at-sea discards of quillback rockfish, assessed using partial at-sea observer data (1999-2001), is estimated at 22% of the quillback rockfish caught by weight in the halibut fishery and 13% in the ZN fishery (Yamanaka and Lacko 2001).

The 2005 commercial TAC for the quillback rockfish species aggregate is 135 t outside and 25 t inside. TACs have remained at this low level since 2002.

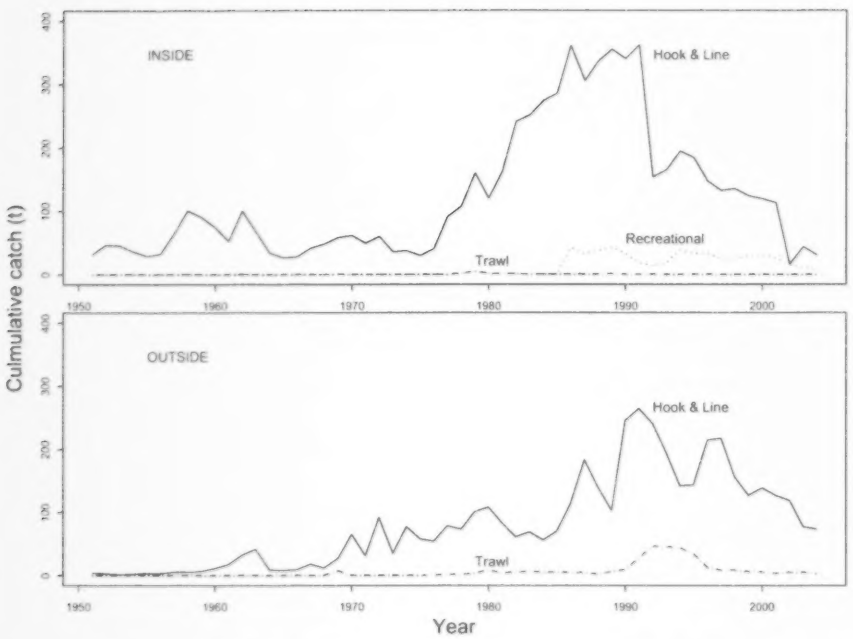

Figure 11. Quillback rockfish cumulative catch for the inside (top) and the outside (bottom) by fishery, commercial hook and line and trawl fisheries and the recreational fishery. The solid line represents the hook and line fishery, dash-dot is trawl, light dots are recreational.

Table 13. Coastwide landings of quillback rockfish 1951 to 2004 from commercial hook and line (H&L), trawl, halibut and recreational (Rec) fisheries, tabulated by year for the inside and outside areas. Commercial H&L and trawl landings between 1951 and 1995 are from sale slips records, between 1996 and 2004 are from PacHarvHL and PacHarvTrawl. Commercial halibut landings between 1995 and 2004 are from PacHarvHL. Recreational landings are converted (0.7 kg) from numbers of fish reported in the Strait of Georgia Creel Survey for the years 1986 to 2004.

Year	Inside				Outside		
	H&L	Trawl	Halibut	Rec[1]	H&L	Trawl	Halibut
1951	31.50	0.00	0.00	0.00	3.60	0.00	0.00
1952	46.20	0.00	0.00	0.00	2.50	0.00	0.00
1953	45.30	0.00	0.00	0.00	0.70	0.00	0.00
1954	35.80	0.00	0.00	0.00	1.70	0.00	0.00
1955	28.70	0.00	0.00	0.00	2.90	0.00	0.00
1956	32.00	0.00	0.00	0.00	3.00	0.00	0.00
1957	64.40	0.00	0.00	0.00	4.90	0.00	0.00
1958	100.20	0.00	0.00	0.00	4.80	0.00	0.00
1959	90.40	0.00	0.00	0.00	6.10	0.00	0.00
1960	74.30	0.00	0.00	0.00	11.20	0.00	0.00
1961	52.40	0.00	0.00	0.00	17.00	0.00	0.00
1962	99.80	0.00	0.00	0.00	31.90	0.00	0.00
1963	67.00	0.00	0.00	0.00	41.40	0.00	0.00
1964	33.70	0.00	0.00	0.00	8.70	0.00	0.00
1965	26.30	0.00	0.00	0.00	7.60	0.00	0.00
1966	27.70	0.00	0.00	0.00	8.80	0.00	0.00
1967	41.60	0.00	0.00	0.00	17.60	0.00	0.00
1968	47.90	0.00	0.00	0.00	11.50	0.04	0.00
1969	57.60	0.59	0.00	0.00	19.90	7.14	0.00
1970	61.10	0.00	0.00	0.00	64.90	0.00	0.00
1971	49.00	0.00	0.00	0.00	31.00	0.00	0.00
1972	59.60	0.00	0.00	0.00	91.50	0.00	0.00
1973	35.40	0.00	0.00	0.00	34.70	0.00	0.00
1974	37.20	0.00	0.00	0.00	77.10	0.00	0.00
1975	29.70	0.00	0.00	0.00	57.40	0.00	0.00
1976	40.60	0.00	0.00	0.00	54.00	0.11	0.00
1977	90.70	0.00	0.00	0.00	76.90	1.21	0.00
1978	106.00	1.57	0.00	0.00	71.50	1.37	0.00
1979	155.00	4.75	0.00	0.00	97.50	3.17	0.00
1980	118.50	1.29	0.00	0.00	99.50	8.35	0.00
1981	161.70	0.84	0.00	0.00	79.40	3.21	0.00
1982	240.23	0.91	0.00	0.00	55.32	5.29	0.00
1983	251.17	0.14	0.00	0.00	62.47	6.03	0.00
1984	273.53	0.36	0.00	0.00	50.33	5.32	0.00
1985	285.20	0.37	0.00	0.00	64.66	5.12	0.00
1986	318.15	0.53	0.00	42.00	108.70	4.28	0.00
1987	272.59	0.53	0.00	32.08	177.95	4.72	0.00
1988	297.85	0.48	0.00	37.61	138.25	1.71	0.00
1989	311.31	0.69	0.00	42.69	95.83	6.52	0.00
1990	306.76	0.09	0.00	33.06	236.02	9.11	0.00
1991	343.26	0.02	0.00	18.35	236.09	27.81	0.00
1992	139.63	0.15	0.00	13.59	194.07	46.28	0.00
1993	146.66	0.00	0.00	18.14	148.26	45.54	0.00
1994	154.63	0.03	0.00	39.70	98.02	43.84	0.00
1995	151.30	0.09	0.05	32.69	106.86	33.70	2.79
1996	112.45	0.16	0.32	33.82	196.78	12.60	4.93
1997	108.32	0.03	0.02	24.08	206.69	7.99	2.47
1998	110.00	0.02	0.14	24.91	140.14	8.43	7.26
1999	93.77	0.00	0.03	29.83	116.24	5.85	4.48
2000	87.30	0.00	0.04	31.59	123.36	5.14	9.77
2001	86.26	0.00	0.16	26.40	112.55	3.12	10.75
2002	0.97	0.00	0.00	15.08	97.98	5.21	15.45
2003	32.63	0.00	0.00	10.69	57.65	5.03	14.25
2004	21.82	0.00	0.01	8.67	56.85	2.48	13.94

[1]converted to weight using 0.7 kg

2. Recreational Catch

The presence of quillback rockfish in relatively shallow water (median 60 m) has made this species a regular quarry by recreational fishers, especially in the Strait of Georgia. Although they can be caught all year round, most of the catch is taken in the summer months when participation in the recreational fishery peaks.

In recent years the number of quillback rockfish caught in the recreational fishery may have declined due in part to the lower overall abundance in inside waters but also from a combination of reduced overall effort (participation) in the Strait of Georgia recreational fishery, lowered bag limits throughout all of British Columbia, and the recent implementation of Rockfish Conservation Areas (Maynard pers. comm. 2005). Most quillback rockfish caught are taken as bycatch associated with the targeting of other species, primarily salmon.

Recreational catch is assessed annually in the Pacific region through a creel survey in portions of the Strait of Georgia and assessed coastwide every five years nationally through a mail-in survey of recreational fishing in Canada (http://www.dfo-mpo.gc.ca/communic/statistics/recreational/canada/2000/index_e.htm). For the first time in 2000, the National survey of recreational fishing reported the catch (in numbers of fish) of rockfish (all species combined) by management region (Table 14).

Table 14. National survey of recreational fishing reported catch of rockfish (all species), in numbers of fish for 2000.

Outside	**Total number of rockfish (all species)**	**346,022**
	Queen Charlotte Is.	30,421
	North Coast	51,060
	Central Coast	68,582
	Barkley Sound	80,899
Inside	**Total number of rockfish (all species)**	**530,630**
	Johnstone Strait	84,099
	Strait of Georgia	446,531

The Strait of Georgia creel survey has provided an annual estimate of recreational catches (in numbers of fish), primarily for salmon but secondarily for groundfish and other species, since 1986. The number of months and landing sites surveyed over the years has varied but as many as 50 landing sites are monitored throughout the Strait of Georgia from Sooke in the south to Brown's Bay in the North. Quillback rockfish are estimated from this survey by applying a 32% proportion to the overall rockfish catch (Collicutt and Shardlow 1992) then converting numbers to weight by applying an average weight (0.7 kg). Quillback rockfish catch estimated in the Strait of Georgia creel survey is shown in Table 13, and is approximately 9 t in 2004.

There is a discrepancy in the recreational catch estimates, in 2000, between the National Survey and the Pacific Region Strait of Georgia Creel Survey, but there are no independent means of verifying catch in this fishery. Estimates of quillback rockfish

catch extrapolated (numbers multiplied by 32% proportion of all rockfish that are quillback rockfish, multiplied by an average weight of 0.7 kg) from the National Survey for the inside fishery are on the order or 119 t where as the Pacific Region Creel Survey estimates 32 t. The majority of the quillback rockfish catch, in the inside area, is taken in the recreational fishery. The 2004 estimate of quillback rockfish caught in the recreational creel survey in the Strait of Georgia is 9 t.

An estimate of recreational catch for the outside area, in 2000, based on extrapolations from the National Survey is 78 t.

3. First Nations Fisheries and Aboriginal Traditional Knowledge

The report writers followed the COSEWIC guidelines for the collection of aboriginal knowledge. The only required Wildlife Management Board contact was the *Nisga'a Joint Fisheries Management Committee* who reported that they had "no additions or comments to their status [quillback rockfish]" (Nyce pers. comm. 2005).

There is little information readily available to understand either present day or historical traditional use of quillback rockfish to the several coastal First Nation bands along British Columbia's coast, and therefore this aspect of the report is incomplete. Given the accessibility of this species to fishing, they have likely always been an important component of aboriginal fisheries. Quillback rockfish were probably caught both intentionally as well as incidentally while pursuing other fish resources including other rockfish species, halibut and lingcod. Early ethnographers all recognized the importance of the "various specimens of cod" as important to a variety of coastal First Nations (Boas 1895), but according to Stewart (1975) explicit reference to rockfishes as a subgroup is absent in the early ethnographies. Archaeological records of *Sebastes sp.* based on the presence of otoliths, skulls, and pelvic girdle elements are typically only classified to the genus (i.e., *Sebastes*) and therefore species information is absent (Stewart 1975).

Catch summary

In summary, the early history of catch records for quillback rockfish, and all rockfishes in general, is not species specific and typically lumped with other groundfish or other rockfish. The discarding of rockfishes, including quillback rockfish has most likely occurred in the past but the level of the discarding prior to 100% observer programs for commercial trawl fisheries in 1995 and partial observer coverage in hook and line fisheries in 1999 is unknown. The mortality associated with discarding is known to be high for all the fisheries and at this time is considered 100%. Estimated cumulative catches of quillback rockfish coastwide from DFO sources by area are shown in Figure 11 and Table 13. Recreational catch and effort by species can not be estimated on an annual basis for all areas of the coast. This is a concern, as is the lack of catch statistics from the Aboriginal fisheries.

POPULATION SIZES AND TRENDS

Search effort

Commercial catch and effort data recorded on logbooks from the directed rockfish hook and line fishery (ZN) are stored in the DFO database PacHarvHL. Research fishing survey data are stored in the DFO database GFBio. Submersible survey videos and visual observations are contained within the DFO database PacGFVideo.

Abundance

1. Area swept bottom trawl surveys

Trawl surveys have been be used to estimate biomass for quillback rockfish. These expansions from area swept bottom trawl survey data should be considered a minimum biomass as trawls are not able to survey in rocky reef habitats, the primary habitat type for quillback rockfish. Catchability for quillback rockfish in trawls is <1. Figure 12 illustrates the areas surveyed by trawls on the BC coast and Table 15 shows the corresponding stratified random bootstrapped biomass estimates from these bottom trawl surveys. A minimum biomass estimate from the trawl surveys for quillback rockfish for the outside waters is 407 t.

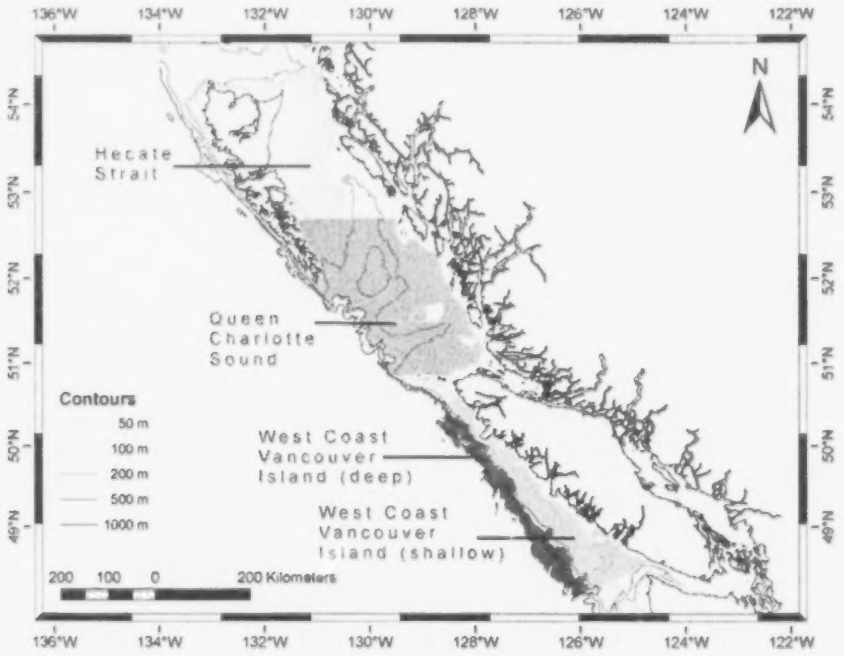

Figure 12. Trawl survey areas on the outside.

Table 15. Stratified random bootstrapped biomass estimate from bottom trawl surveys. Relative error is the CV of the bootstrapped estimates. This is considered a minimum estimate based only on trawlable bottom.

Survey	Year	Median Index (t)	Lower C.I.	Upper C.I.	Relative Error
West Coast V.I. (shallow)	2004	61	23	182	0.49
West Coast V.I. (deep)	2003	0	0	0	-
QC Sound Synoptic	2004	230	94	732	0.51
Hecate Strait	2003	116	45	338	0.50

2. Hecate Strait assemblage trawl survey

The Hecate Strait trawl survey is stratified by area and depth with fixed stations within depth strata (Choromanski et al. 2002). The sampling grid (10 nm2) extends throughout Hecate Strait, between the Queen Charlotte Islands and the mainland, from Dundas Island in the north to Juan Perez Sound in the south (Figure 13). Between 82 and 105 trawl tows were made during the 11 surveys conducted between 1984 and 2003. A small proportion of the tows catch quillback rockfish in this survey because of the low relief (trawlable) bottom types targeted in this trawl survey. Quillback rockfish aggregate over rocky reef habitats and are not typically found in these low relief areas.

The CPUE index for quillback rockfish derived from the survey is shown in Figure 14. Two and three stage averages of the CPUE series show a declining trend through the series from the mid 1980's to the mid 2000's (Figure 15). Biomass estimates for quillback rockfish are shown in Table 16. These should be considered minimum estimates as the survey does not cover the primary rocky reef habitat for quillback rockfish. Biomass as low as 4 t and as high as 260 t is estimated for the Hecate Strait survey area.

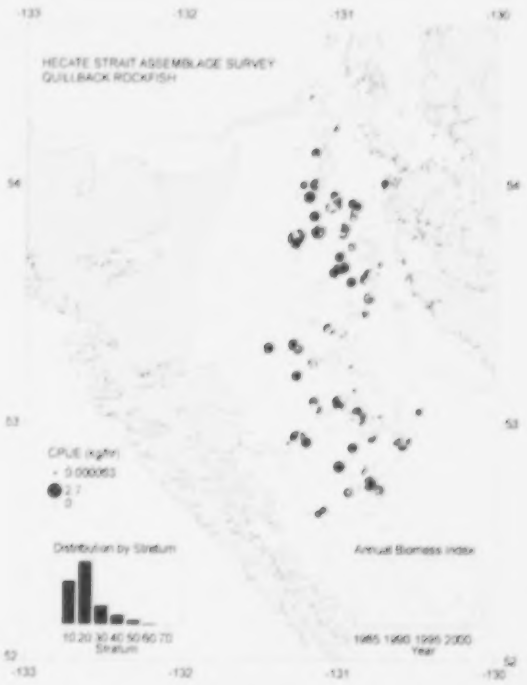

Figure 13. Hecate Strait assemblage survey 1984 – 2003 area showing the distribution of quillback rockfish catch.

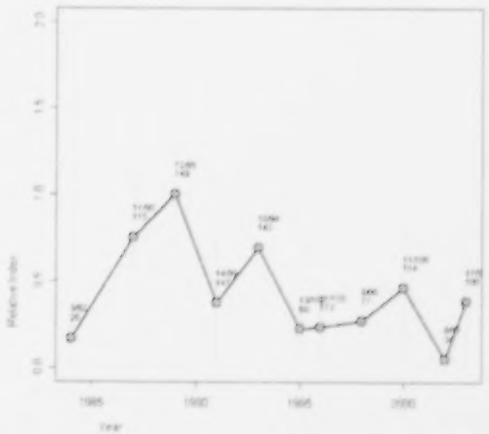

Figure 14. Relative indices (median bootstrapped) for quillback rockfish from the Hecate Strait multi-species assemblage survey. The bootstrapped 95% confidence limits are shown as vertical lines. The numbers above each point indicate the number of sets in which quillback rockfish were caught and the total number of sets in the survey (top numbers), and the total catch weight (kg) of quillback rockfish (bottom number).

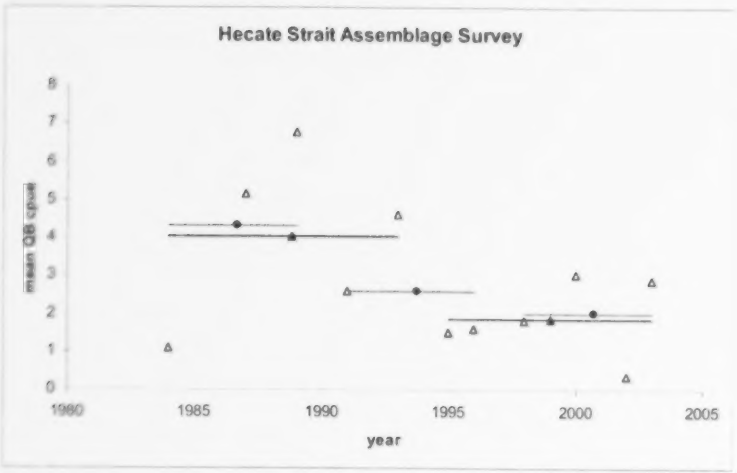

Figure 15. Relative indices for quillback rockfish from the Hecate Strait multi-species assemblage survey CPUE series (from Figure 14) averaged in two and three stages.

Table 16. Quillback rockfish biomass in tonnes by year from area swept trawl estimates from the Hecate Strait assemblage survey. Median biomass (t), 95% lower and upper confidence values are presented.

Year	Median	Lower CI	Upper CI
1984	43	14.19	114.68
1987	194	68.06	631.22
1989	258	72.40	718.35
1991	98	25.26	282.15
1993	184	43.12	715.53
1995	60	25.88	155.14
1996	64	29.05	125.84
1998	71	27.96	202.44
2000	124	44.12	301.25
2002	14	4.01	28.30
2003	116	40.92	315.01

3. Visual towed camera survey in the Strait of Georgia

A video survey was conducted in 2003, in a portion of the Strait of Georgia (Figure 16). A depth-stratified random design was employed where the survey area was divided into two depth strata of 10-50 m and 51-100 m and overlain with a 1 km^2 grid (Martin and Yamanaka 2004). Twenty-two blocks were randomly selected from each depth strata. Transects within the block were targeted in areas of hard bottom and/or high slope.

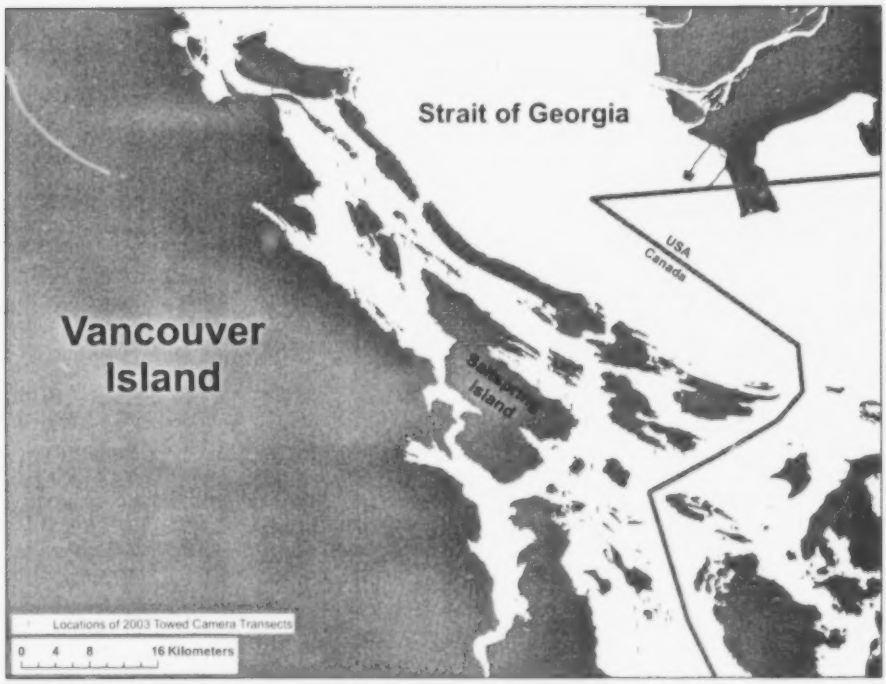

Figure 16. Locations of the towed camera transects in the Strait of Georgia in 2003.

Quillback rockfish density over all 42 transects for combined habitat types was approximately 4227 individuals km^{-2}, though habitat-specific densities for bedrock and boulder were 12283 individuals km^{-2} and 7632 individuals km^{-2}, respectively. Summary statistics for these densities are shown in Table 17. Using the density estimate over all habitat types, quillback rockfish abundance is 2.23 million over the survey area (527 km^2).

Table 17. Quillback rockfish densities estimated from visual fish counts using an ROV in the Strait of Georgia in 2003.

Density # per km²	Bedrock	Boulder	Cobble	Mixed Coarse	Sand	All Habitat Types
Mean	12,283	7,632	252	405	5,506	4,226
Std Error	6,239	2610	252	110	5,506	1,364
Median	0	0	0	146	0	0
Std Dev	24,163	14,059	758	594	18,264	8,521
Range	69,988	50,789	2275	2370	60,576	45,902
Minimum	0	0	0	3	0	0
Maximum	69,988	50,789	2,275	2,373	60,576	45,902
95% CI	13,381	5,348	582	226	12,270	2,762

4. Visual submersible survey in Juan Perez sound

A submersible survey was conducted in Juan Perez Sound on the East side of the Queen Charlotte Islands in May 2005 (Figure 17) (Yamanaka unpublished data). The area was divided into a survey grid of 2 km^2, each grid block was stratified by habitat then randomly selected grid blocks were surveyed. Dive transects were conducted within the grid block using the submersible Aquarius to visually enumerate quillback rockfish using line transect methodology to estimate density and abundance (Buckland et al. 1993). Probability density functions (PDF) are constructed from fish observations and used in conjunction with estimates of line length to estimate the density of quillback rockfish populations (Thompson 1992).

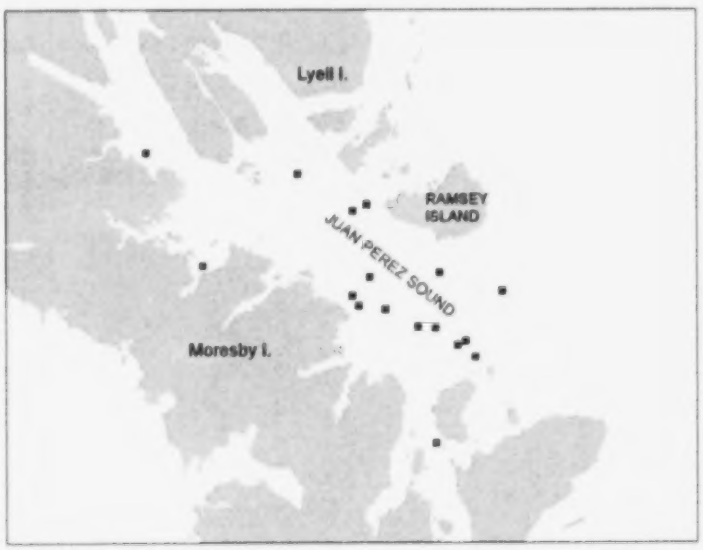

Figure 17. Locations of the 2005 submersible dives conducted in Juan Perez Sound, Queen Charlotte Islands.

Habitat was assessed using a bathymetric position index (BPI) derived from multibeam bathymetry and enhanced with a backscatter filter (Weiss 2001). Fine and course scale BPI values identified ridge tops and ridges and with the addition of the backscatter, soft bottom areas were filtered out of the analysis. Three habitats were identified, rock ridge tops, rock ridges and all other low slope habitat areas.

Submersible transects were overlain on the habitat maps and partitioned by habitat type. PDFs were constructed from the quillback rockfish observations by habitat type and densities estimated (Yamanaka and Grandin unpublished data). These densities were then expanded to an abundance estimate over each habitat area within Juan Perez Sound. By adding together the abundance estimates by habitat type, the total abundance of quillback rockfish for the survey area (217.63 km^2) in Juan Perez Sound is 2,078,160 fish (Yamanaka and Grandin unpublished data).

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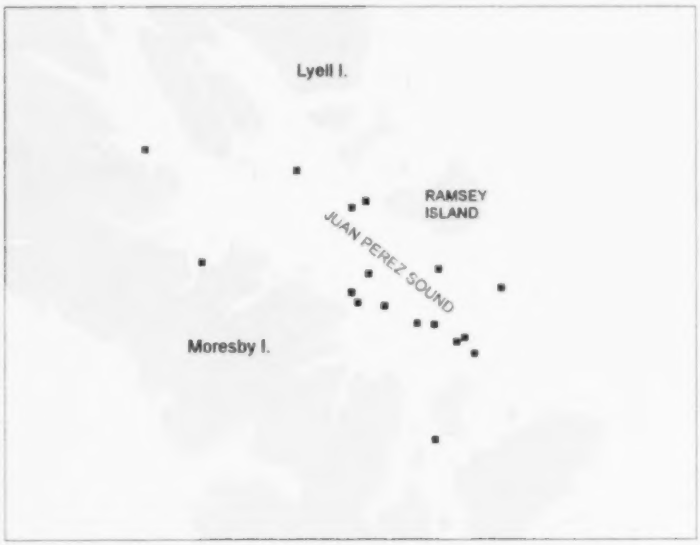

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Fluctuations and trends

1. Coastwide commercial catch data

1a. Commercial catch and effort

Population trends for quillback rockfish can be constructed from the commercial ZN fishery catch and effort data recorded on logbooks. This is the longest time series of catch per unit of effort (CPUE) data available. The majority of the fishing outside of the Strait of Georgia management region is conducted with longline gear. Inside the Strait of Georgia is largely a handline fishery. Catch per unit effort data from the commercial ZN fishery are shown in Figure 18 by gear type and area.

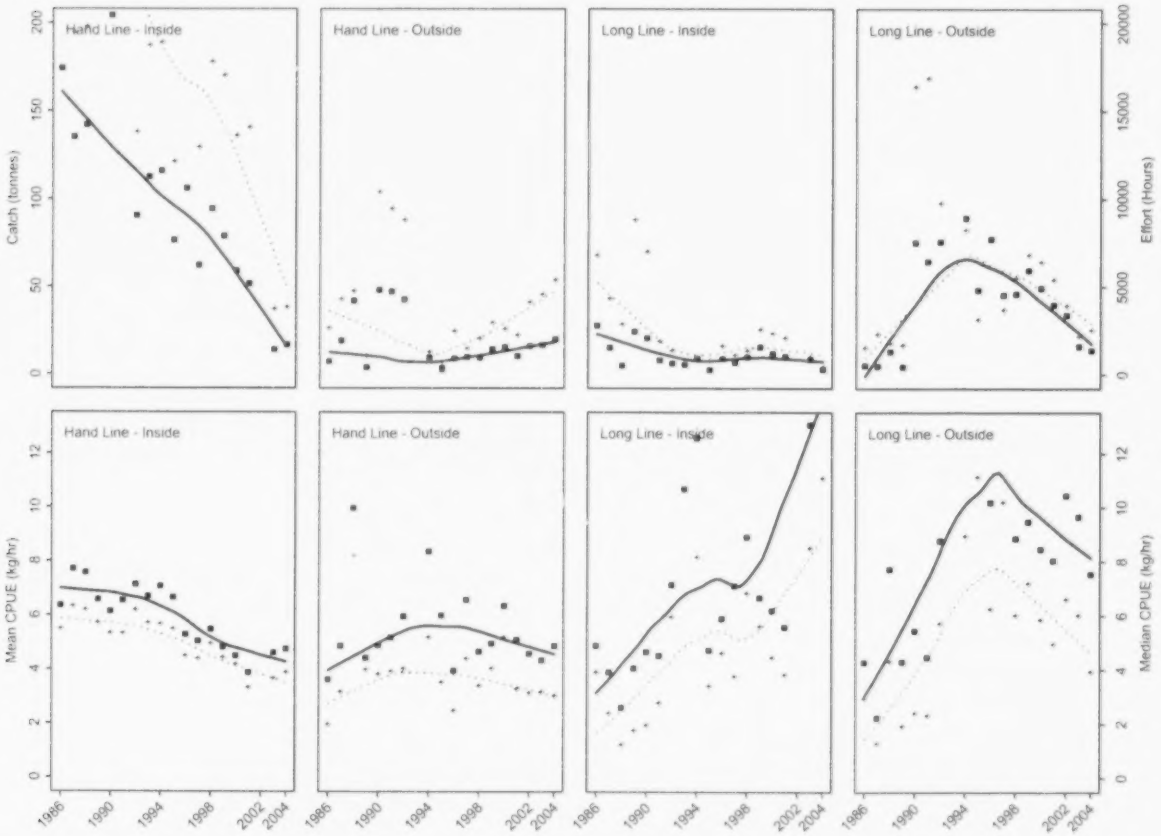

Figure 18. Commercial catch data by gear type and area for quillback rockfish in the directed ZN fishery. Upper panels display catch (square) and effort (plus). Solid line is a local regression fit of catch, dotted line is a local regression fit of effort. Lower panels display mean (square) and median (plus) catch per unit of effort. Solid line is a local regression fit of mean CPUEs, dotted line is a local regression fit of median CPUEs.

There are many problems with interpreting abundance trends derived from fishery CPUE data. The most significant of these, for quillback rockfish, are the lack of independent catch data to verify log book recorded catch and effort data and the influence of management actions applied to the fishery. Changes in management of the fishery alters fisher behaviour which influences catch and effort data. Many significant management changes have occurred over the CPUE time series. In 1991, prior to limited entry, DFO announced its intention to limited the number of licences in the ZN fishery. Particularly high CPUE, prior to 1991, may be due to an increased effort to record landings and become eligible for a license. Landings may also have been inflated or incorrectly identified to species during this period as no dockside verification was in place. The implementation of a limited entry fishery for the inside in 1992 and the outside in 1993 reduced the number of licences (74 and 183 respectively) in both fisheries from over 2400 coastwide. Fishing effort decreased substantially. Prior to 1995 and the implementation of the 100% dockside monitoring program, landed weights by species could not be independantly verified on logbooks.

TACs for quillback rockfish have steadily declined from 1991 to 2002 (~1000 t to 205 t). As with other fishery dependent catch indices, CPUE is affected by the catch, lowering TACs will lower CPUEs. Fishermen claim that decreasing TACs result in lowered CPUE as fishing becomes more non-directed and quillback rockfish is avoided. Between 2001 and 2002, TACs were dramatically reduced, as part of the Rockfish Conservation Strategy, by 50% in the outside area and 75% in the inside area. For the inside area, this fishery is also purposely drawn out to suppy a constant supply of fish to the live market. CPUE indices from this commercial catch data are likely uninformative and reflect changes in management rather than population trends.

1b. Commercial groundfish trawl fishery (T)

Catch per unit effort time series can also be constructed from the commercial groundfish trawl fishery using at-sea observer recorded catch (Figure 19). Quillback rockfish caught in the trawl fishery is not a significant portion of the overall catch. As with the hook and line fishery, catch rates are influenced by management measures, primarily declining TACs. Hence, declining trends in CPUE indices over a period of declining TACs is difficult to interpret and may not reflect declines in actual abundance but avoidance of species by fishers.

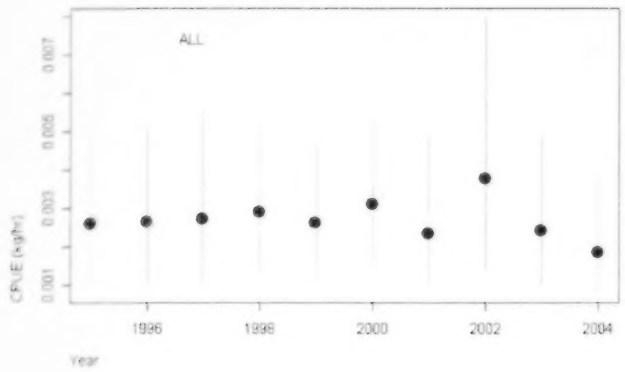

Figure 19. Commercial trawl observer recorded quillback rockfish cpue (kg/hr) by year.

2. Biological samples

2a. Forklengths

Quillback rockfish mean forklengths and mean ages from samples coastwide are shown in Figures 20 and 21. Both forklengths and ages vary widely as a result of small sample sizes in some years. There is an increasing trend in forklength over the time series. Size at age varies by area and samples have not been consistently collected on a comparable spatial scale over the time series.

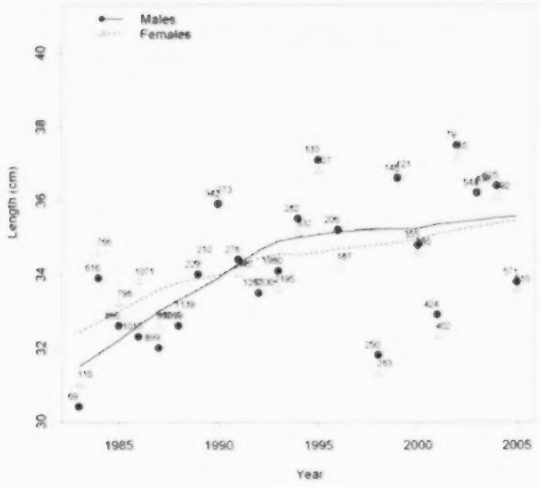

Figure 20. Mean lengths by year for quillback rockfish (males solid circles, females open triangles). Numbers of fish, by sex and year are shown. The lines shown are produced from the best-fit locally weighted regression of mean length by year (males solid line, females dotted line).

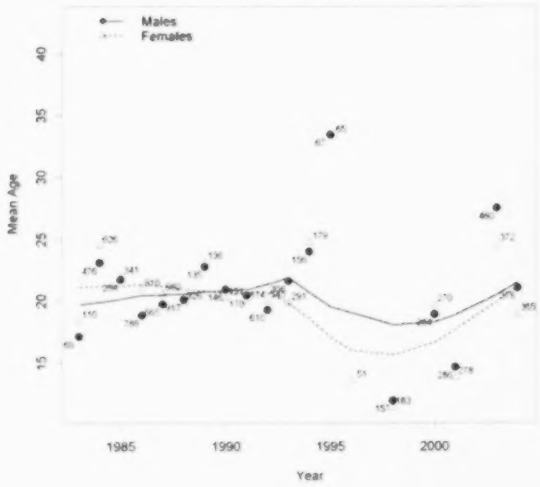

Figure 21. Mean ages by year for quillback rockfish (males solid circles, females open triangles). Numbers of fish, by sex and year are shown. The lines shown are produced from the best-fit locally weighted regression of mean length by year (males solid line, females dotted line).

3. Research Surveys

3a. PHC SSA surveys

The International Pacific Halibut Commission (IPHC) conducts a Standardized Stock Assessment (SSA) longline survey annually to assess Pacific halibut stock abundance. In 1995 and annually since 2003, catch data for species other than halibut have been collected (Yamanaka et al. 2004, Lochead et al. *in prep*). The survey set locations differed in 1995 from those in 2003/04 (shown in the left panel of Figure 22). Only those sites common in all years, were used to calculate a CPUE index (shown in the right panel of Figure 22).

Quillback rockfish are caught at low levels throughout the survey. Spatial distribution of quillback rockfish catch rates are shown in Figure 23 for 2003 and 2004 combined. A catch rate index is constructed from the IPHC SSA survey and shown in Figure 24 and Table 18. The catch rate index is highly variable and there is no trend in abundance detected over the survey years.

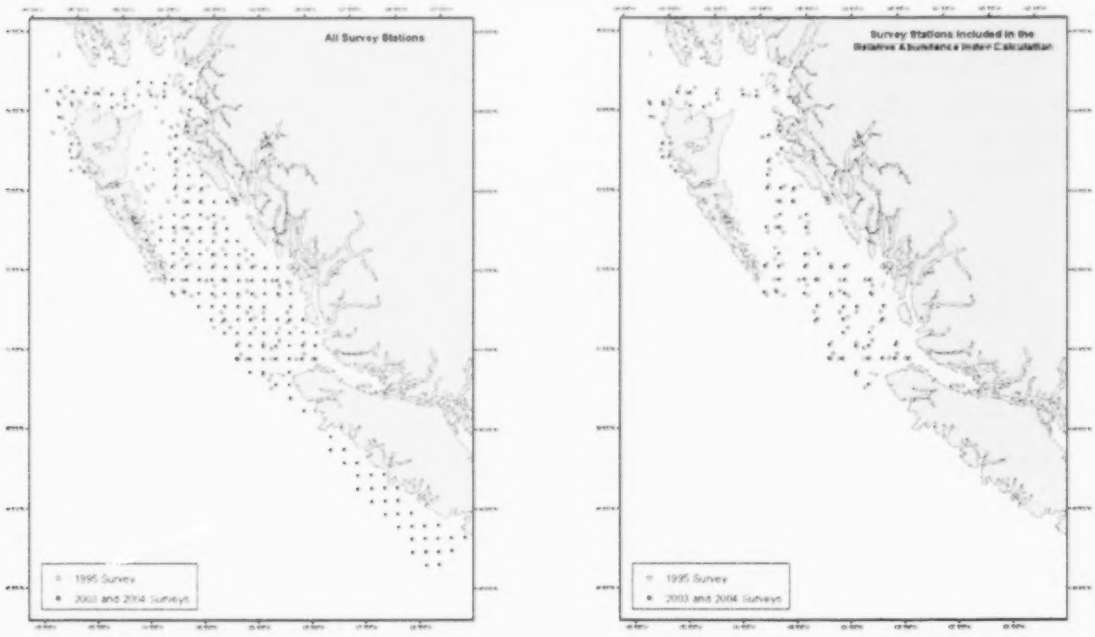

Figure 22. IPHC SSA survey locations for 1995, 2003 and 2004 surveys in BC (left panel). Open circles represent survey sites in 1995, filled circles represent survey sites in 2003 and 2004. Overlapping sites surveyed in all years that were included in the CPUE index (right panel).

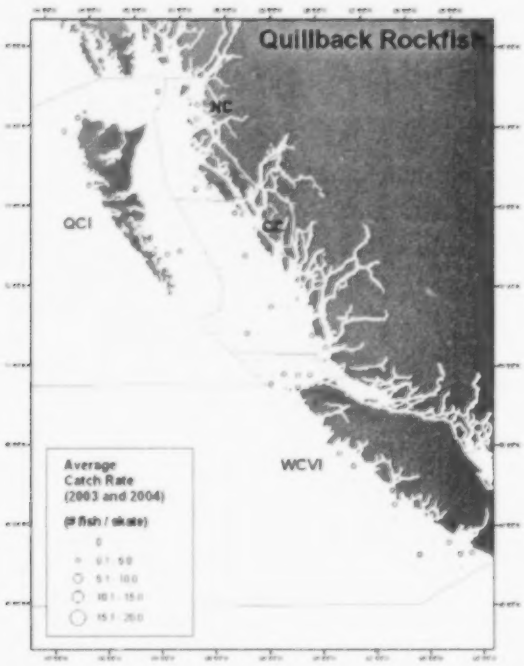

Figure 23. Spatial distribution of quillback rockfish catch rates from the IPHC SSA survey in BC for the years 2003 and 2004 combined.

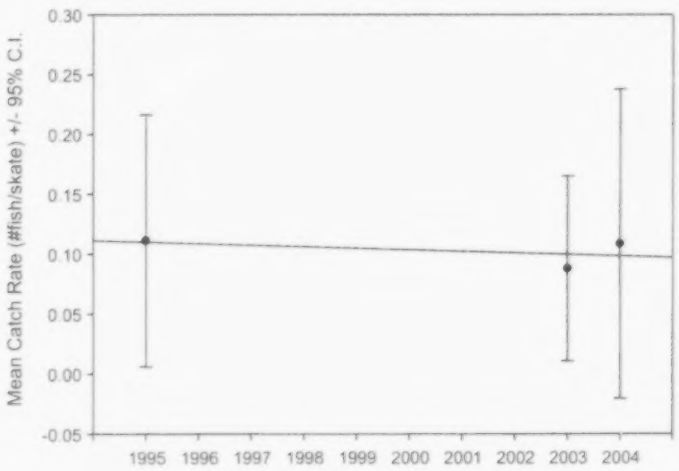

Figure 24. Quillback rockfish mean catch rates and 95% confidence intervals (CI) by year for the IPHC SSA survey. Slope of regression line is not significantly different from zero ($r^2 = 0.0001$, $F = 0.03$, $df = 1,213$, $p = 0.86$).

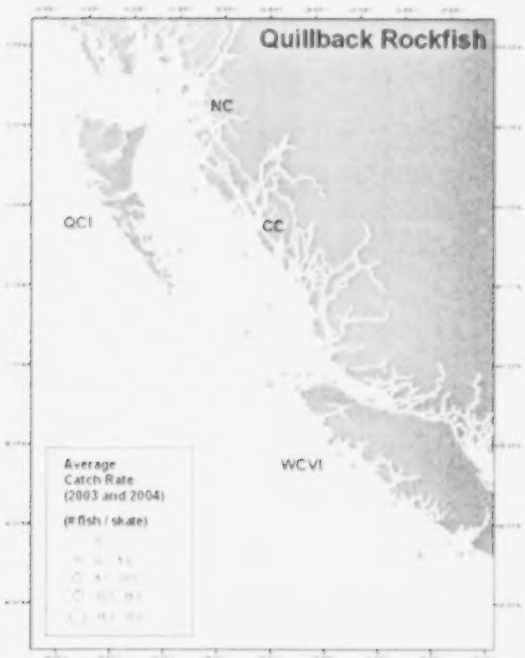

Figure 23. Spatial distribution of quillback rockfish catch rates from the IPHC SSA survey in BC for the years 2003 and 2004 combined.

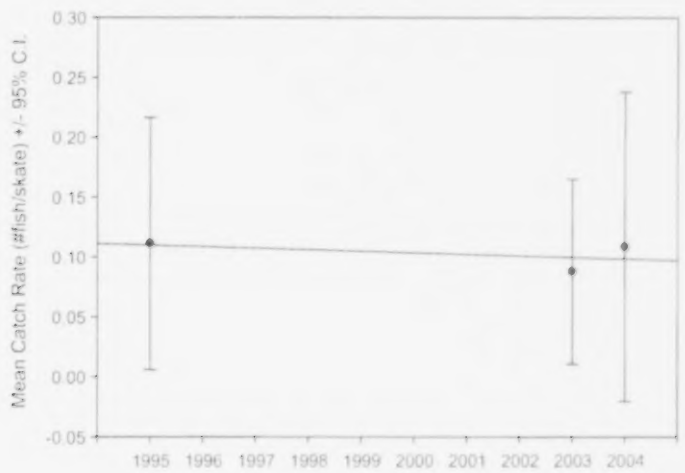

Figure 24. Quillback rockfish mean catch rates and 95% confidence intervals (CI) by year for the IPHC SSA survey. Slope of regression line is not significantly different from zero ($r^2 = 0.0001$, $F = 0.03$, $df = 1,213$, $p = 0.86$).

Table 18. Summary statistics for the quillback catch rate in numbers of fish per skate of fishing gear for the the IPHC SSA survey by year in BC.

Catch Rate (#fish/skate)	1995	2003	2004
Mean	0.11	0.09	0.11
Standard Error	0.05	0.04	0.06
1st Quartile	0	0	0
Median	0	0	0
3rd Quartile	0	0	0
Mode	0	0	0
Standard Deviation	0.48	0.32	0.53
Sample Variance	0.23	0.10	0.28
Minimum	0	0	0
Maximum	2.80	1.50	3.75
Total Number of Sets	81	67	67
Confidence Interval (95.0%)	0.11	0.08	0.13

3b. Research Charter Survey for yelloweye rockfish

Research charters conducted to index yelloweye rockfish in 1997/8 and 2002/03 also intercepted quillback rockfish (Kronlund and Yamanaka 2001, Yamanaka et al. 2004). The first surveys were conducted in September 1997 and May 1998 in four study areas; two on the west side of the Queen Charlotte Islands and two on the upper west coast of Vancouver Island (Figure 25). These were followed five years later by surveys conducted in September 2002 and May 2003. CPUE indices for quillback rockfish are shown in Figure 26 and Table 19. The CPUE index is highly variable but there is a significant negative trend in catch rate over the survey series from 1997 - 2003.

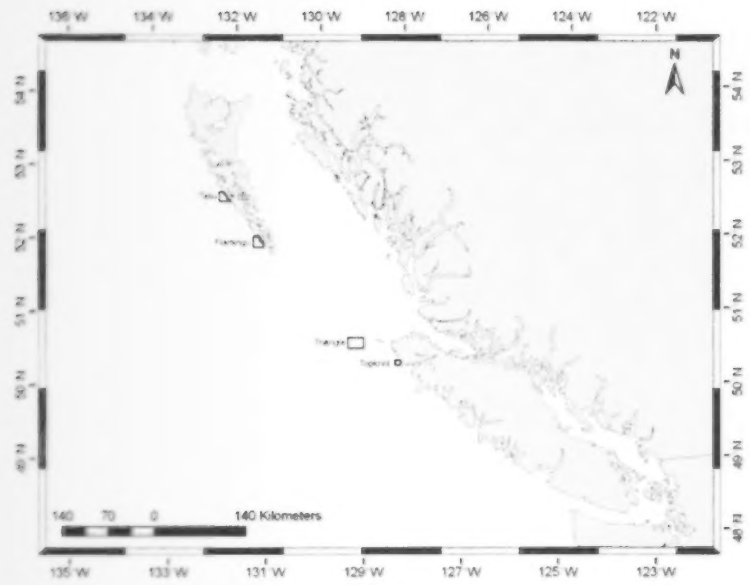

Figure 25. Four study sites surveyed for yelloweye rockfish by chartered fishing vessels in 1997/98 and 2002/03. Paired sites, lightly and heavily fished, off the Queen charlotte Islands (Tasu and Flamingo) and the North West of Vancouver Island (Triangle and Topknot)

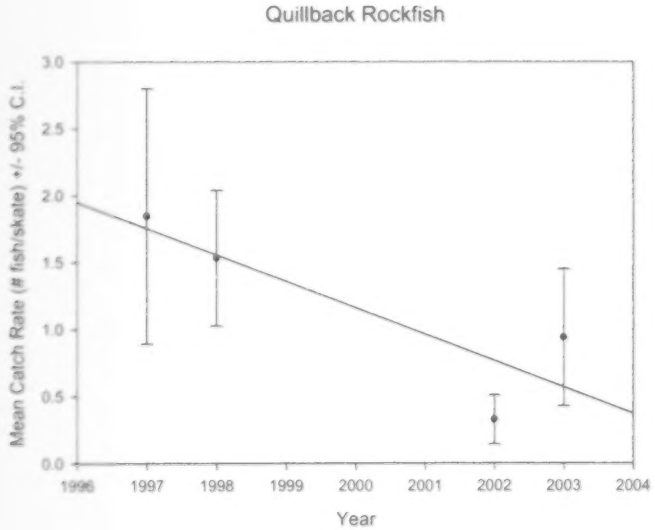

Figure 26. Quillback rockfish mean catch rates and 95% confidence intervals from the charter vessl surveys in the outside area. Slope of the trend line is significantly different from zero (r^2 = 0.075, F = 13.37, df = 1,165, p = 0.003 *).

Table 19. Summary statistics for the quillback catch per unit effort for the research charters.

Quillback Rockfish	Fall 1997	Spring 1998	Fall 2002	Spring 2003
Mean	1.85	1.53	0.33	0.94
Standard Error	0.4670	0.2518	0.0906	0.2537
1st Quartile	0	0	0	0
Median	0.80	0.80	0.00	0.20
3rd Quartile	2.60	2.50	0.40	0.70
Mode	0	0	0	0
Standard Deviation	2.6004	1.7262	0.6144	1.6639
Sample Variance	6.7619	2.9796	0.3775	2.7686
Minimum	0	0	0	0
Maximum	9.40	6.00	2.60	6.60
Total Number of Sets	31	47	46	43
Confidence Interval (95.0%)	0.9538	0.5068	0.1825	0.5121

3c. Longline survey Strait of Georgia

Longline surveys were initiated in the Strait of Georgia to develop a fishery independent abundance index and provide biological data for the assessment of population parameters for this area (Lochead and Yamanaka 2004, 2006, *in prep*). This survey was conducted in 2003 and 2004 in DFO statistical areas (SA) 12 and 13 and in SA 14 through 20, 28 and 29 in 2005 (Figure 27). No differences in CPUE from the two surveys in areas 12 and 13 are detected (Lochead and Yamanaka 2006). However, the CPUE is significantly lower for quillback rockfish in the southern portion (surveyed in 2005) when compared with the northern portion (surveyed in 2004 and 2004) of the Strait of Georgia (Figure 28 and Table 20).

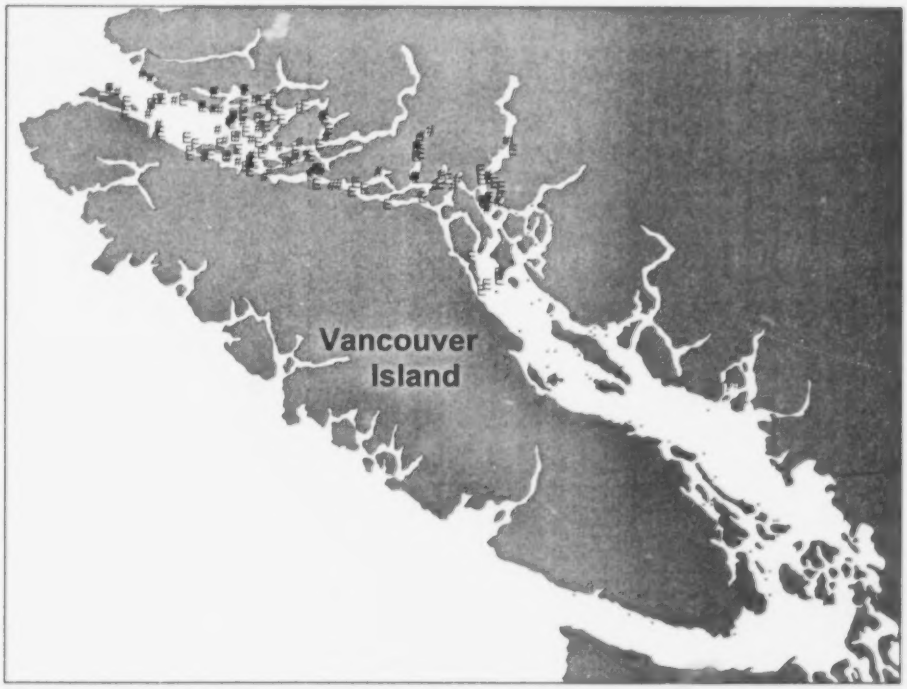

Figure 27. Longline survey fishing set locations by year. Survey was conducted in SA 12 and 13 in 2003 (plus) and 2004 (triangle) and in SA 14 through 20, 28 and 29 in 2005 (square).

3c. Longline survey Strait of Georgia

Longline surveys were initiated in the Strait of Georgia to develop a fishery independent abundance index and provide biological data for the assessment of population parameters for this area (Lochead and Yamanaka 2004, 2006, *in prep*). This survey was conducted in 2003 and 2004 in DFO statistical areas (SA) 12 and 13 and in SA 14 through 20, 28 and 29 in 2005 (Figure 27). No differences in CPUE from the two surveys in areas 12 and 13 are detected (Lochead and Yamanaka 2006). However, the CPUE is significantly lower for quillback rockfish in the southern portion (surveyed in 2005) when compared with the northern portion (surveyed in 2004 and 2004) of the Strait of Georgia (Figure 28 and Table 20).

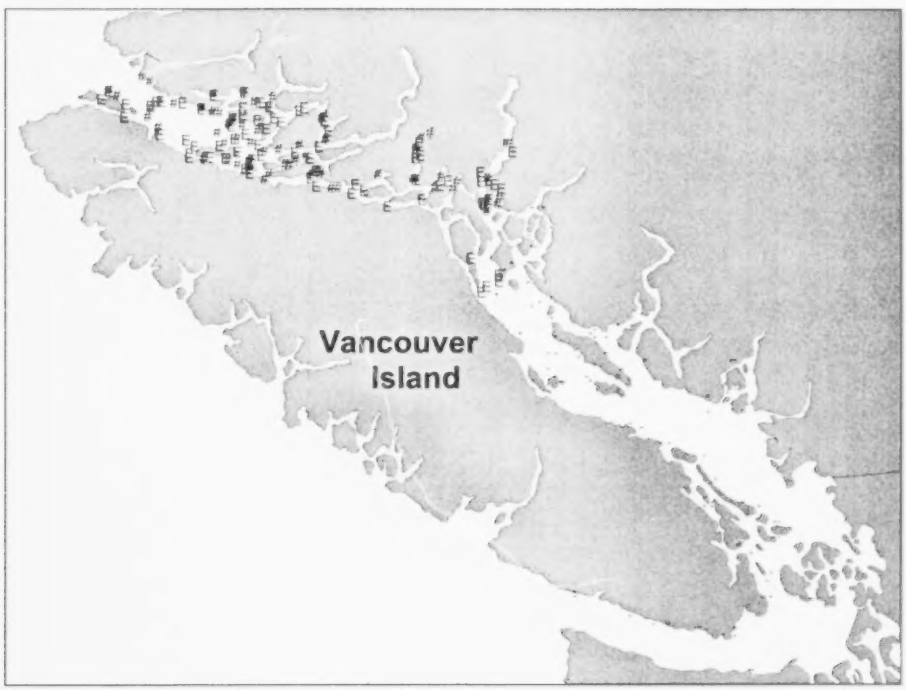

Figure 27. Longline survey fishing set locations by year. Survey was conducted in SA 12 and 13 in 2003 (plus) and 2004 (triangle) and in SA 14 through 20, 28 and 29 in 2005 (square).

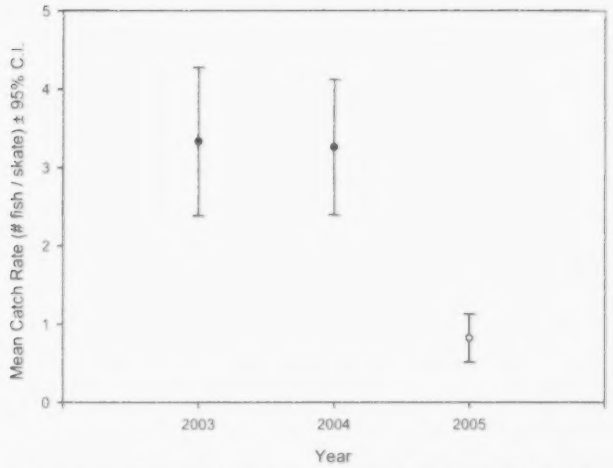

Figure 28. Longline survey CPUE by year in the Strait of Georgia. The survey was conducted in the north (SA 12 and 13) in 2003 and 2004 and in the south (SA 14 through 20, 28 and 29) in 2005.

Table 20. Summary statistics for the quillback rockfish catch rate in the longline survey in the Strait of Georgia by year. The survey was conducted in the northern portion of the Strait of Georgia in 2003 and 2004 and in the southern portion in 2005.

Quillback Rockfish	2003	2004	2005
Mean	3.33	3.26	0.82
Standard Error	0.4751	0.4320	0.1552
1st Quartile	0	0.50	0
Median	1.75	2.00	0
3rd Quartile	4.50	5.00	1.00
Mode	0	0	0
Standard Deviation	4.2493	3.4561	1.4641
Sample Variance	18.0566	11.9444	2.1434
Minimum	0	0	0
Maximum	23	13.5	9
Total Number of Sets	80	64	89
Confidence Interval (95.0%)	0.9456	0.8633	0.3084
Difference among years: Kruskal-Wallis test, H = 35.3324, p <0.0001**, df = 2			

3d. Submersible Survey in Strait of Georgia

Submersible surveys were conducted in 1984 and 2003 to index abundance of inshore rockfish in the Desolation Sound and Sechelt areas of the Strait of Georgia Figure 29 and Table 21 (Richards and Cass 1985, Yamanaka et al. 2004). A comparison of the numbers of fish observed per transect between common sites and depths surveyed between 1984 and 2003 are shown in Figure 30. A significant decline in quillback rockfish counts per transect were found between the two surveys.

Figure 29. Location of submersible survey dives conducted in 1984 and 2003 in the Strait of Georgia.

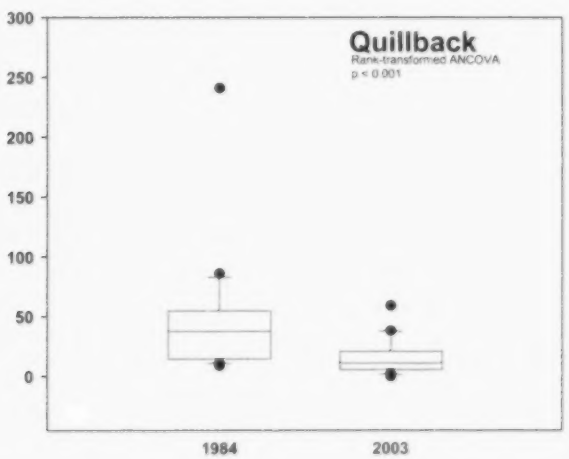

Figure 30. Visual counts of quillback rockfish per transect during submersible survey dives conducted in 1984 and 2003 in the Strait of Georgia (Yamanaka et al. 2004).

Table 21. Summary statistics for quillback rockfish counts per transect during the 1984 and 2004 submersible surveys (Yamanaka et al. 2004).

Counts per transect	Quillback	
	1984	2003
Mean	47.4	16.7
Standard Error	10.79	3.36
Median	38	11.5
Standard Deviation	49.44	15.01
Sample Variance	2443.95	225.19
Range	232	59
Minimum	9	0
Maximum	241	59
Confidence Level (95.0%)	22.50	7.02

3e. Jig Surveys

Johnstone Strait

Jig fishing surveys were conducted in 1986, 1987, 1988, 1992 and 2004 at 10 study sites in the Johnstone Strait area of the Strait of Georgia (Figure 31) (Hand and Richards 1989, Yamanaka and Richards 1993, Yamanaka unpublished data). Quillback rockfish are targeted in these surveys. CPUE data from these surveys are used to index abundance of quillback rockfish and are shown in Figure 32 and Table 22.

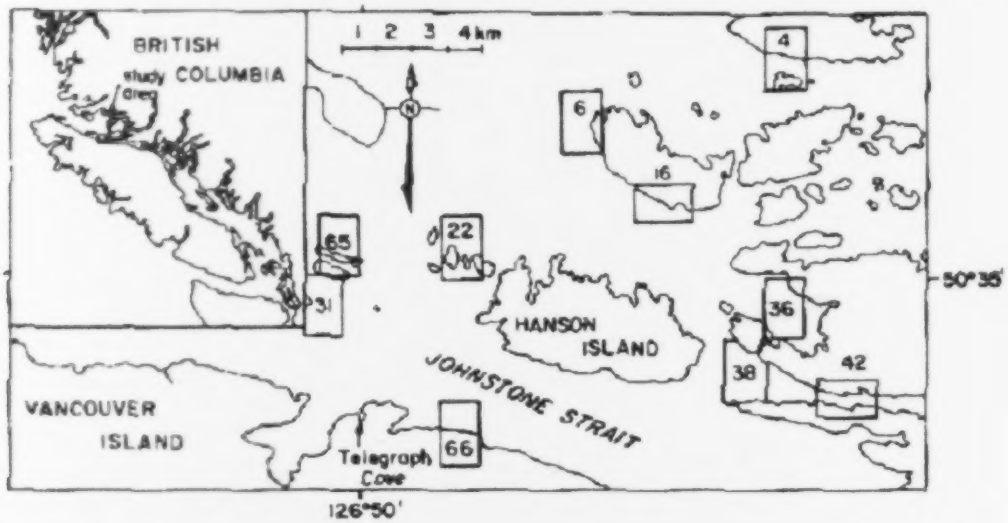

Figure 31. Jig survey sites in Johnstone Strait from Yamanaka and Richards (1993).

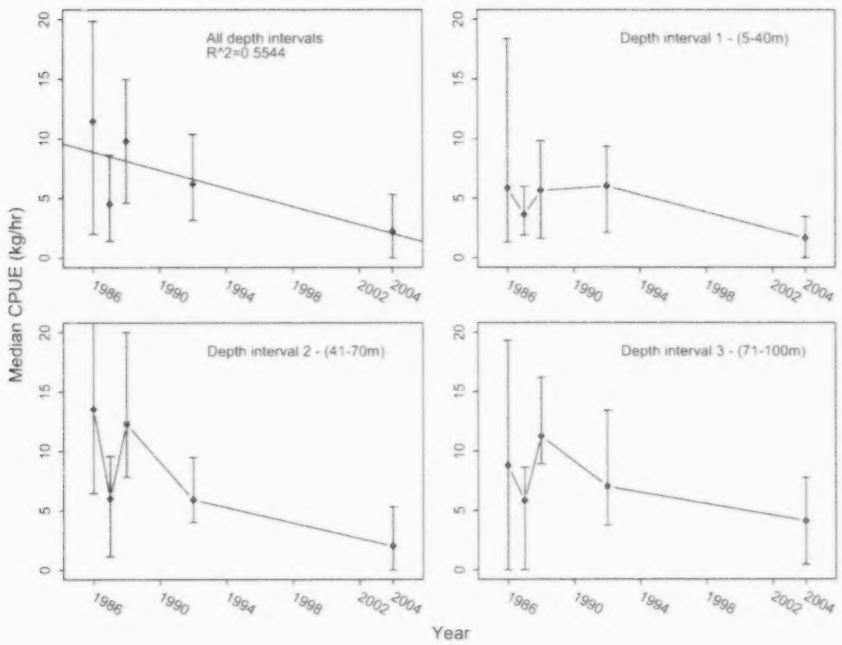

Figure 32. Johnstone Strait jig survey quillback rockfish median CPUE and 95% confidence intervals overall sites by year. Median CPUE (95% CI) for all depth intervals combined (upper left) regression fit to median values, shallow depth interval 1-41 m (upper right), mid-depth interval 41-70 m (lower left) and deep depth interval 71-100 m (lower right).

Table 22. Quillback rockfish CPUE summary statistics overall depths from the jig surveys conducted at study sites in Johnstone Strait.

Quillback Rockfish	1986	1987	1988	1992	2004
Mean	14.35	5.82	11.25	8.03	3.58
Standard Error	1.4603	0.5273	0.9897	0.8097	0.4733
1st Quartile	2.00	1.40	4.61	3.15	0
Median	11.69	4.51	9.78	6.20	2.22
3rd Quartile	19.85	8.63	14.97	10.37	5.32
Mode	0	0	0	0	0
Standard Deviation	15.0351	5.4794	9.9950	9.0524	4.7562
Sample Variance	226.0553	30.0242	99.8999	81.9464	22.6218
Minimum	0	0	0	0	0
Maximum	77.83	23.07	64.20	80.23	33.86
Total Number of Sets	106	108	102	125	101
Confidence Interval (95.0%)	2.8956	1.0452	1.9632	1.6026	0.9389

Quillback rockfish CPUE in the early surveys 1986-88 are highly variable and as the time series progresses, a significant declining trend is evident. A simple regression through the median CPUE values by year is described by:

CPUE = 763.82 - 0.38*year

Based on using this regression line, between 1986 and 2004 there has been a 75% decline in quillback rockfish abundance over the 18 years of the survey conducted in Johnstone Strait, the northern portion of the inside waters. The decline in catch rate over time is likely not linear over the 18 year period given the reduction in catch quota between 1991 and 2004 and in particular since 2002 when quotas were reduced by 75% from the previous year.

Strait of Georgia

Jig fishing surveys targeted to index the abundance of lingcod were conducted in the southern Strait of Georgia in Statistical Areas 18 and 19 (Figure 33). Jig fishing was conducted at two depth intervals, a shallow 1-25 m and a deep 25-50 m in survey sites in 1993 and again in 2005. Surveys were examined for quillback rockfish catch rates (Figure 34 and Table 23) (Yamanaka and Murie 1995, Haggarty and King 2005). There were significant declines in CPUE between 1993 and 2005 (Kruskal-Wallis p=0.003 shallow and p=0.000 deep Haggerty and King 2005).

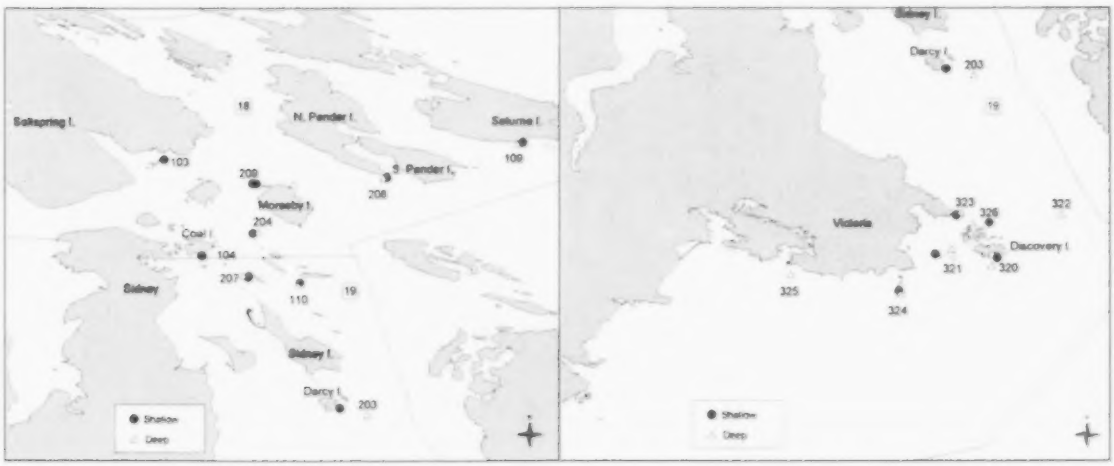

Figure 33. Lingcod jig fishing survey locations in the southern Strait of Georgia statistical areas 18 and 19 from Haggarty and King (2005).

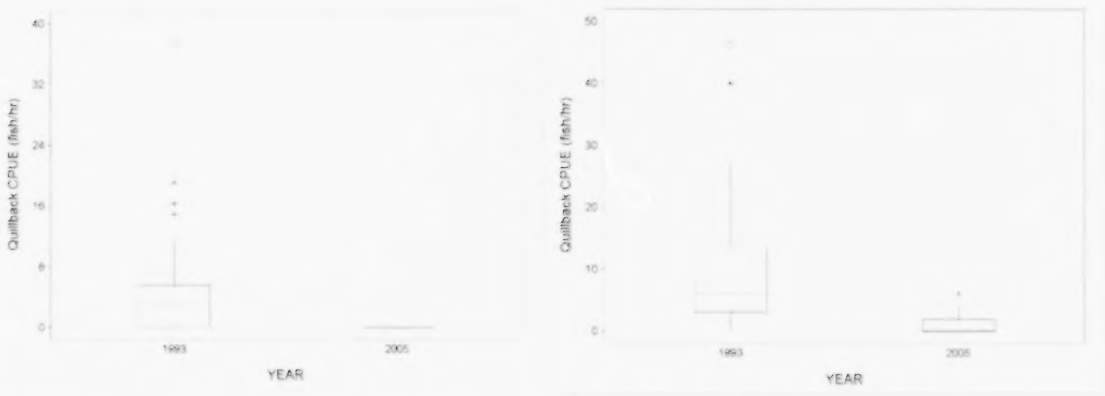

Figure 34. Quillback rockfish catch rates in the lingcod jig surveys in the southern Strait of Georgia by year. CPUE in the shallow 1-25 m (left panel) and deep 25-50 m (right panel) depth intervals are shown by year from Yamanaka and Murie (1995) and Haggarty and King (2005).

Table 23. Quillback rockfish descriptive statistics for catch rate during the lingcod jig surveys (Yamanaka and Murie 1995, Haggarty and King 2005).

quillback CPUE	1993	2005	1993	2005
	Shallow depths		Deep depths	
N	52	16	52	18
LO 95% CI	2.4629	0.0	6.9844	0.1943
MEAN	4.335	0.0	9.645	1.1111
UP 95% CI	6.2071	0.0	12.306	2.0279
SD	6.7245	0.0	9.5566	1.8436
C.V.	155.12		99.083	165.92
MINIMUM	0	0.0	0	0
MEDIAN	2.795	0.0	6.16	0
MAXIMUM	37.5	0.0	46.15	6

Rescue effect

Repopulation of quillback rockfish through the dispersal of larvae from adults living outside of Canada is likely as there are no physical barriers to dispersal in the marine environment. Quillback rockfish exist both to the north as well as the south of BC.

1. Alaska

Quillback rockfish are managed within the demersal shelf rockfish aggregate (DSR) along with canary, China, copper, rosethorn, tiger and yelloweye rockfishes. DSR are managed jointly by the state of Alaska and the National Marine fisheries Service in the Southeast outside subdistrict (SEO) and managed solely by the State in the internal state water subdistricts. The 2004 stock assessment for DSR is based on an exploitable biomass of 20,168 t for yelloweye rockfish, the dominant species of the DSR complex, for the SEO. The allowable biological catch (ABC) for yelloweye rockfish for the SEO was set at 450 t which includes a 10% allowance for the other 6 species of DSR (O'Connell et al. 2004). Quillback rockfish make up about 8% of the DSR catch. There is no quillback rockfish stock assessment in Alaska.

2. Washington

Puget Sound quillback rockfish were petitioned in 1999 but did not warrant listing under the Endangered Species Act (NMFS 2001). During this review three distinct population segments were determined; south Puget Sound, north Puget Sound, including the Canadian Gulf Islands and a coastal population. The Puget Sound quillback rockfish population is below historic levels and considered depressed but no assessment of stock size is available (Palsson pers. comm.). The quillback rockfish population on the outer coast is not assessed.

LIMITING FACTORS AND THREATS

A natural limiting factor for the quillback rockfish population in BC is successive years of recruitment failure. Oceanic conditions such as upwelling and strong onshore drift off the coast of California have been linked to recruitment in Californian rockfishes (Yoklavich et al. 1996). The link between successful recruitment and environmental factors has not been made in BC.

Potential anthropogenic threats to quillback rockfish populations in BC are the fisheries and contaminants from industrial sources. Fisheries in BC are monitored assessed and managed by DFO. DFO's Rockfish Conservation Strategy, initiated in 2002, has implemented RCAs (closed areas) in 20% to 30% of rockfish habitats coastwide, decreased allowable catches by 50 to 75% between 2001 and 2002 and increased the monitoring and stock assessment research for quillback rockfish. Commercial fisheries are managed to total allowable catches through 100% dockside monitoring together with partial at-sea observer programs (100% monitored with groundfish integration). Recreational fisheries are managed by bag limits and monitored by creel surveys in various areas coastwide.

SPECIAL SIGNIFICANCE OF THE SPECIES

There is surprisingly little known about the role this species plays in structuring the shallow rocky reef ecosystem. Aside from their ecological significance, quillback rockfish are an important component in commercial, Aboriginal, and recreational fishing sectors. Quillback rockfish are the most important species supplying the live fish market in BC's lower mainland. This live fish market is the main market for the quillback rockfish fishery in the Strait of Georgia and throughout BC.

EXISTING PROTECTION OR OTHER STATUS DESIGNATIONS

The quillback rockfish does not have any international status designations. Puget Sound quillback rockfish were petitioned in 1999 but did not warrant listing under the Endangered Species Act (Stout et al. 2001). In Canada it receives no individual species protection.

In BC's commercial fishery, quillback rockfish are managed by TACs for an aggregate of rockfish species which also includes copper, China and tiger rockfishes. Commercial coastwide total allowable catch for the aggregate in 2005/06 is 161 t (135 t on the outside and 26 t on the inside). The recent creation of Rockfish Conservation Areas throughout 20 to 30% of rockfish habitats coastwide are intended to protect a portion of quillback rockfish populations from all harvests.

ACKNOWLEDGEMENTS

The authors would like to thank the many DFO research scientists, biologists and technicians, whom over the years have planned and conducted research, collected and archived data on quillback rockfish. Many DFO Groundfish programs and personnel supported the research effort and data included in this report. Direct funding to write this report was provided by Environment Canada.

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Appendix A. Total mortality estimated from Ricker catch curves (1975) for quillback rockfish age data collected from research surveys.

1. The Surveys

a) Research jig fishing

Research jig fishing surveys were conducted in 1986, 1987, 1988, 1992 and 2004 at ten research sites in Area 12, around Johnstone Strait in the northern portion of the inside or Strait of Georgia management region (Richards and Cass 1987; Richards and Hand 1987; Richards et al. 1988; Yamanaka and Richards 1993). In 2001, commercial fishing vessels were chartered to conduct research in Area 12 and fished many of the same jig fishing sites. Quillback rockfish from this experiment were collected for ageing structures and used in stock assessments.

c) DFO longline survey

A longline survey directed for inshore rockfish was conducted in 2003 and 2004. This survey covered the northern portion of the inside area (statistical areas 12 and 13) from Campbell River in the south to Hope Island in the north and employed a depth stratified (40 to 70 m and 71 – 100 m) random design (Lochead and Yamanaka 2004).

2. Age data

Sagittal otoliths collected from surveys are assigned ages using a burnt section technique (MacLellan 1997) at the Pacific Biological Station Ageing Lab. Age data are stored in the PBS groundfish research database GFBio.

To standardize three years of annual surveys into one age analysis, one year was added to the 1986 survey data and one year was subtracted from the 1988 survey data prior to combining ages for the analysis. Similarly, for combining two years of annual survey data, one year was added to the earlier survey to standardize ages for the analysis.

3. Catch curve methods (Ricker 1975 section 2.2 Simple catch curves p. 33)

Age frequencies are constructed in one year age bins and where the age frequency in an annual bin= 0, this age bin is removed. There is no binning of ages. Frequencies are $-\log_{10}$ transformed and the regression performed on all data after the age at which the maximum age frequency occurs. Total mortality, Z is calculated from the slope of the regression line multiplied by 2.3026, as described by Ricker (1975). R^2 values are also presented for the regression line (Figures 1 and 2).

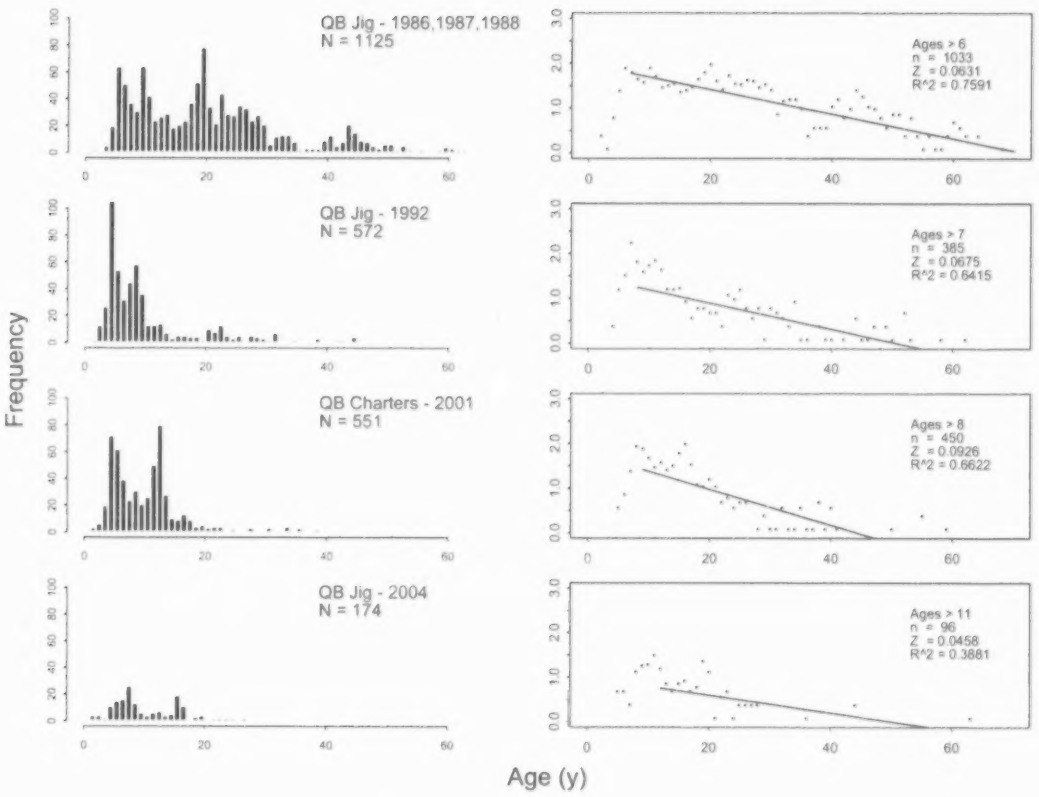

Figure 1. Age frequencies (left panels), log frequencies with regression line and calculated total mortality, Z and r^2 statistic for the research jig fishing surveys in 1986-88 (top), 1992 (second from top), 2001 research charter (second from bottom) and 2004 (bottom).

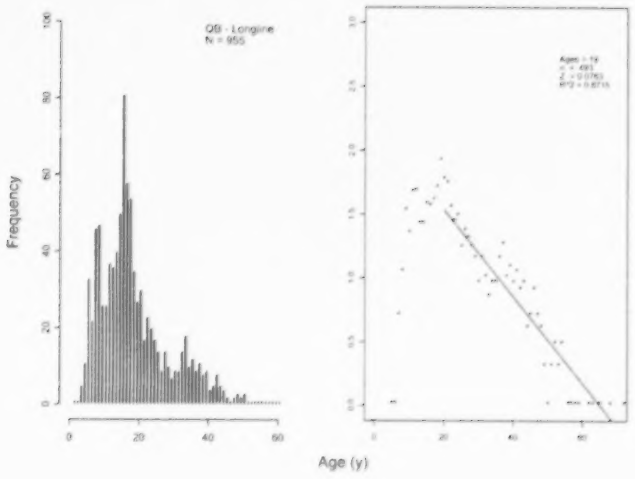

Figure 2. Age frequencies (left panels), log frequencies with regression line and calculated total mortality, Z and r^2 statistic for quillback rockfish from the research longline fishing surveys in Areas 12 and 13 in 2003 and 2004.

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